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# Proceedings: Symposium on Fire in Wilderness and Park Management



## Preface

The Fire in Wilderness and Park Management Symposium was held from March 30 through April 1, 1993, in Missoula, MT. It was sponsored by the U.S. Department of Agriculture, Forest Service, Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, National Wildfire Coordinating Group, The Wilderness Society, Renewable Natural Resources Foundation, Society of American Foresters, and the University of Montana.

Maintaining the primeval character of wildernesses and national parks with fire as a natural process is controversial. How can fire be allowed to play its natural role without unacceptable consequences? In 1983, a major symposium in Missoula on wilderness fire gave impetus to wilderness fire management programs. In 1988, extensive fire in wildernesses and national parks brought national attention to the problems of meeting wilderness goals with fire.

This symposium, one decade after Missoula's first major wilderness fire conference, examined past lessons and future opportunities. The presentations and discussions were centered around three major themes:

- Are goals and policies being met?
- Understanding and managing constraints.
- Implementing programs and future opportunities.

A major change over the past 10 years is the recognition that different approaches to managing fire are needed to satisfy the goals and constraints of large and small wilderness areas in remote and some not-so-remote locations.

The symposium was attended by 421 fire managers, wilderness managers, educators, researchers, and members of the general public. The presentations included 26 papers and 6 panel discussions. A poster session of 65 exhibits was scheduled for one evening. The posters and 10 commercial exhibits were available for viewing throughout the symposium.

I wish to acknowledge the planning committee members for their diligent, imaginative, and enthusiastic efforts in planning the symposium. Special thanks are due Chuck Spoon, as program chairman, and Bill Fischer, as poster chairman, for their long hours of dedicated work. The planning committee members were:

- Steering Committee—Jim Brown (Chair), Intermountain Research Station, Missoula, MT; Bob Mutch, Intermountain Research Station, Missoula, MT; Rod Norum, National Park Service, Boise, ID; and Ron Wakimoto, The University of Montana, Missoula, MT.
- Program—Chuck Spoon (Chair), Lolo National Forest, Missoula, MT; Dave Bunnell, Flathead National Forest, Kalispell, MT; Bob Clark, Bureau of Land Management, Boise, ID; Dave Cole, Intermountain Research Station, Missoula, MT; Sue Husari, USFS, Pacific Southwest Region, San Francisco, CA; Steve Morton, USFS, Northern Region, Missoula, MT; Tom Nichols, National Park Service, San Francisco, CA; and Jan van Wagtendonk, Yosemite National Park, CA.
- Posters—Bill Fischer, Intermountain Research Station, Missoula, MT.
- Tours—Dan Bailey, Lolo National Forest, Missoula, MT.
- Commercial Exhibits—Dan Mangan, Missoula Technology and Development Center, Missoula, MT.
- Local Arrangements—Gerry Baertsch, The University of Montana, Missoula, MT.
- Proceedings—Bert Lindler, Intermountain Research Station, Ogden, UT.
- Publicity—Dave Tippets, Intermountain Research Station, Ogden, UT.

Managers have made significant progress in returning fire to wilderness and parks since the prescribed natural fires were first allowed in the 1970's. Because fire is a primary ecological force, its presence is often essential to preserve the natural character of wilderness areas. In most situations, however, managers must consider how fire will affect recreation, safety, existing plant communities, endangered species, air quality, and adjacent nonwilderness land. This symposium should help managers deal with the challenge of using fire to maintain primeval conditions while satisfying other wilderness goals and constraints.

James K. Brown
Research Forester

# Proceedings: Symposium on Fire in Wilderness and Park Management

## Missoula, MT, March 30-April 1, 1993


**Technical Coordinators:**

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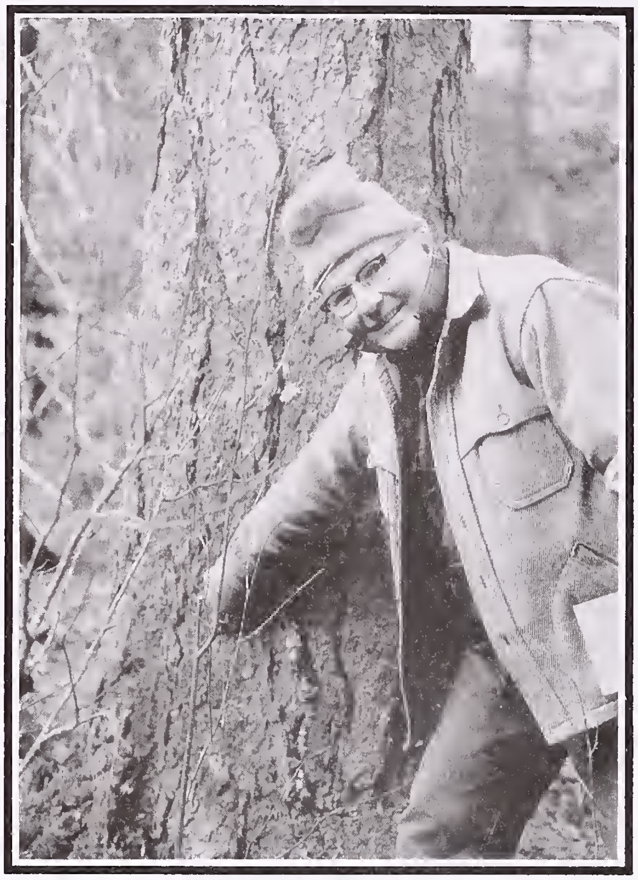

**MIRON L. (BUD) HEINSELMAN**
**1920-1993**

Passionate scientists are not common. Bud Heinselman was one of the few. He was a fine ecologist, who loved his work on the natural role of fire in forest ecosystems, especially in the Boundary Waters Canoe Area Wilderness in his native northern Minnesota. Bud is well known for developing Heinselman's fire regime classification. It is still used to describe fire's natural role in American forests. Bud worked long and hard, but with joy and enthusiasm. He left a nearly completed book on the Boundary Waters ecosystem when he died of a stroke on February 28, 1993, following a brief illness with a rare blood disorder.

Bud not only studied the Boundary Waters Canoe Area, he loved it deeply. He traveled it in all seasons, and took annual 3-week canoe trips with his wife of 50 years, Fran. He put his love of the area into practice by organizing, lobbying, writing, speaking, and, finally, persuading the public and politicians to amend the Wilderness Act, the first and only time it has been amended. The amendment gave the Boundary Waters additional wilderness status by eliminating most of the special exceptions that had applied there. The time and effort he devoted to this cause would have staggered most people, but Bud's intense dedication fueled his labors.

Forest Service scientist, University of Minnesota professor, conservationist, activist, hunter and fisherman, friend of many, respected opponent of others—Bud Heinselman. May his spirit roam the lakes and forests of the north country he worked so hard to understand and perpetuate.

—by Bob Lucas,
friend and retired wilderness researcher

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# Goals and Policies



# Challenge Address: Fire in Wilderness and Park Management

**David F. Jolly**

**Abstract**—The challenge for resource managers is to understand and appreciate the wilderness resource. We must embrace a philosophy that allows natural fire to play its natural role, within social and political realities. As we alter the natural processes, we alter the very essence of wilderness. The public will demand our accountability, and we need to pursue financing to administer and monitor wilderness fire. These fires are cost-efficient; usually they involve one-tenth or less the cost of suppressing fire. Suppression of wilderness wildfires must use strategies, tactics, and restoration fitting to these lands.

Today I welcome you all to Missoula and to the Northern Region of the Forest Service. This is the third generation of conferences held in Missoula to talk about fire in wilderness. The evolution of topics spanned has been remarkable. The conference that starts today is dedicated to taking a broader view of fire in wilderness by examining wilderness goals and values, and how fire management plans and strategies can meet these goals.

Prior to the 1988 fire season, 4.8 million acres of wilderness and nonwilderness lands in the Northern Region were managed to allow the use of prescribed natural fire. This region had one of the most active natural fire programs in the Forest Service: 378 prescribed natural fires treated over 180,000 acres between 1972 and 1988. During that period, only nine of the prescribed natural fires were declared wildfires when some element of the prescription was exceeded.

Of those nine, most were classified as wildfires because of technicalities, such as lack of funds or fires crossing corridor boundaries. The most significant was the Canyon Creek Fire in 1988, a quarter-million-acre fire that burned 118,000 acres outside of wilderness.

During the years prior to 1988, the cost of monitoring the prescribed fires, including the few that were classed as wildfires, was well under $10 per acre.

## POLICY REVIEWS

As a result of the 1988 fire year in Yellowstone and elsewhere, the Secretaries of Agriculture and the Interior conducted a department-level review of prescribed fire policies. During that time all wilderness fire plans were suspended. The Forest Service then reviewed the findings with our own task force. Following the Chief's direction, we began to bring our wilderness fire plans back on line. In the Northern Region, we now have 3.3 million acres once again approved, with more than another million expected back in 1993.

While this is a modest beginning, we have a considerable distance to go. In November 1989 the Chief's office issued a letter from the Director of Fire and Aviation Management that stated:

> Our objective is to have revised and approved plans, which meet all of the Review Team's recommendation and direction in Forest Service Manual 5140, by the 1990 fire season. If you have difficulty in accomplishing this objective, please explain.

The General Accounting Office also had some words for the Federal Agencies in its December 5, 1990, report. They stated:

> The Review Team reaffirmed that fire is beneficial and even necessary to wildlands. The Review Team's report stated that where fire has been a historic component of the environment it is essential to continue that influence, and that attempts to exclude fire from such lands could result in unnatural ecological changes and increased risks created by accumulations of fuels on the forest floor.

They went on to say:

> Implementation of the revamped prescribed fire program has been limited because federal fire management agencies have been slow to approve fire management plans for individual Parks and Wildernesses. These fire management plans are a pre-requisite for restarting the program. Additionally, the prescribed fire program faces both resource limitations and resistance by some fire and wilderness managers. The funds available to manage a prescribed fire program fall far short of the amount managers say they need. Also, some fire and wilderness field office managers still subscribe to the philosophy of suppressing all fires.

## SUPPRESSION PHILOSOPHY

I want you to know that I do not subscribe to that philosophy and I do not want the Northern Region's line officers to subscribe to it.

It is unethical in wilderness where fires burned until the early part of this century. We fought them vigorously for 50 to 60 years. Fire is the single most influential natural force operating in our wildernesses. That is the most significant reason to allow fire to play its natural role—even though there are other reasons many specialists could list.

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David F. Jolly is Regional Forester, Northern Region, Forest Service, U.S. Department of Agriculture, Missoula, MT.

It is not cost effective—"pay me now or pay me later!" And, later is usually bigger and the fire effects will probably be different.

It is ecologically incorrect. In fact, we need to figure out how to use prescribed fire on other multiple-use lands, to return health, vigor, and biodiversity to our ailing forests, which tend to be filled with pathogens from years of fire suppression. But that is another topic—closely aligned with our Ecosystem Management program.

## DIVERSE RESOURCES

Now, I know that wildernesses and parks come in many sizes and shapes. With over 500 units in the National Wilderness Preservation System, Congress has given us a great challenge. Wilderness ranges in size from 2 acres to over 8 million, from literally on people's doorsteps to vast ecosystems in Alaska. Wilderness goals and values, while resting on the cornerstone of the Wilderness Act of 1964, are of necessity constrained by the reality of location, proximity to population, recreation, history, and the various specifics contained in the more than 100 other Acts that created those wildernesses.

The type and frequency of fire use programs appropriate to meet wildernesses values may vary from wilderness to wilderness. In some cases, it may be only through management ignitions that fire can be returned to the wilderness and nonwilderness ecosystems. We are well aware of the potential challenges and risks associated with management ignitions. When nature lights the match, it gets to share the credit and some of the blame. When we do it, we get all of both.

Generally—at least in the larger wildernesses of the West—lightning still lights the fires frequently enough to give us opportunities to proceed, based on our fire plans. We still need to take a good look at all our options, for we have some small wildernesses with social constraints just as some of you do.

I believe that as we look to the future, we must put the atypical summer of 1988 in perspective and reconcile it with the successful, historical performance of the prescribed fire program. At stake is the health and vitality of the wilderness resource. Without fire, wilderness becomes little more than a semiprimitive, nonmotorized recreation area. It loses an important wilderness attribute. It is no longer whole.

Without fire, we contribute to the extinction of plant and animal species. Without fire, the forest terminates in the last stage of succession, losing many of the plants and animals that exist in the other parts of the natural cycles. Or, it may become susceptible to a fire regime that is unnatural in terms of its size or its effects.

Chief Dale Robertson, at the International Wildland Fire Conference in Boston, in July 1989, quoted philosopher Tyron Edwards when he said, "Hell is truth seen too late." The Chief was referring to the type of cooperation necessary in the event of major wildfire emergencies.

But today, I think of those words in terms of the wilderness fire program. The truth is that without fire, the wilderness resource is in a state of decline. We are allowing unnatural systems to be the rule rather than the exception. The species composition and biodiversity of our greatest remaining natural areas are threatened. Understories have grown up close to the crowns of the old monarch pines, larches, and firs. Without fire soon, the ladder fuels will carry the fire into the crowns of these giants and they will not survive. We must get on with the job.

## THE CHALLENGE

And so here is the challenge, as I see it.

First, for ourselves, as agency personnel: get an understanding of and a deep appreciation for the wilderness resource down deep into your bones. Catch a vision of what wilderness really is. Wild wilderness today is still the geography closest to perfection that exists on this planet. We need to keep our hands off wilderness and the processes that shape it—to the maximum extent possible. Relative to fire, we need to embrace a philosophy toward allowing natural fire to play its historical role, within social and political realities. This is our unique responsibility as stewards of wilderness. To the extent we alter the natural process, we alter the very essence of wilderness.

Where Congress has challenged us with a wilderness in a social setting—which appears beyond our capability to ensure containment of natural fire—we may need to rely on a management ignition program with the goal of replicating a natural fire cycle, so far as possible. This, surely, will compromise the pure wilderness values—but it may be our only option.

Second, for the public, a comprehensive wilderness fire education program to lay the groundwork of grassroots understanding of and support for prescribed fire—both natural and ignited—must begin. I believe we already have considerable support. This education program must be as vigorous as the Leave No Trace, minimum impact camping campaign has been.

We must tell the public and the wilderness recreationists, and the outfitters and the local communities, that there is some risk in the program. There may be periods of smoke. Not all fires are going to be small and benign. But, the result will be real wilderness, for their children and grandchildren.

Third, all wildernesses need to have a fire plan. Certainly by the time this conference is held again, I hope we will have planned for and returned fire to all units of the National Wilderness Preservation System. And just because we have fire plans, let's not implement those plans in a feeble, fainthearted manner. I expect the wilderness community will soon demand our accountability if they see inordinate numbers of natural ignitions suppressed, or no ignitions occurring in those wildernesses that call for us to do the igniting.

Fourth, we must aggressively pursue the financial resources to administer and monitor prescribed fires in the wilderness. Prescribed fire is cost effective, usually only a fraction of the cost of suppressing the fire. We need to tell this story to Congress and create a prescribed fire fund similar to the Fire Fighting Fund, which, I believe—in the long run—will save the government millions of dollars.

Failing that, I think it highly appropriate for the Chief's office to allocate a sufficient account of project dollars to assure our ability to monitor these fires. And I intend to do what I can for the financial support of the program in the Northern Region.

Fifth, suppression of wildfires in wilderness must use the type of strategies, tactics, and restoration that is fitting for these lands. We must not leave behind the scars of suppression, which remain for decades following the fire.

As Regional Forester of the Northern Region, I hope we will move forward aggressively and be leading the way. I say that humbly, because we may have some opportunities that some of you may not have. With those opportunities we must also shoulder some greater responsibilities. While it is easy to give this essential wilderness program lip service, few agency administrators relish the idea of breaking a big fire on their watch. Undoubtedly it will happen. But without a managed return of fire, we all hasten the coming of the next major ecosystem breakdown. I trust we will bring the best science, leadership, skilled managers, and public support to this program. It deserves it. The wilderness is worth it.

# Political Considerations of Park and Wilderness Management

Jim Bradley

**Abstract**—The basis for subcommittee and congressional support of a natural fire policy and its implementation is discussed. The natural fire program is considered to be of critical importance to quality land management. Natural fire is important because it is based on correct science, which must underlie land management policy, and because we cannot have true wilderness without natural fire.

I work for the Subcommittee on National Parks, Forests, and Public Lands, which is part of the Committee on Natural Resources in the U.S. House of Representatives. My boss is the chairman of this subcommittee, Congressman Bruce Vento from St. Paul, MN. I really would have loved to have been out there in Missoula for this conference because, for both Chairman Vento and I, the natural fire program is of critical importance and we are hoping that as a result of this conference the natural fire program will have a new birth, a reemphasis, a new priority in all the land management agencies because we think it is of critical importance to quality land management in the National Parks and in wilderness areas.

The reason neither Congressman Vento nor I can speak to you personally today is that Congress is in session and it is very difficult for either of us to travel when key legislation is moving through the House.

So that you can understand why our subcommittee is interested in the natural fire program, I should tell you a little bit about what it does. The Subcommittee on National Parks, Forests, and Public Lands has 25 members, 16 Democrats and nine Republicans. It has jurisdiction over any legislation or policy issues dealing with the Bureau of Land Management, National Park Service, and the Forest Service. Because these agencies manage one-third of the land mass of the United States, our subcommittee is very busy. Any time anyone wants to do anything different out in that vast amount of land, it usually takes legislation, and that legislation will be referred to Chairman Vento's subcommittee. As a result, the subcommittee actually is the busiest subcommittee in Congress.

In a typical Congress, which is a two-year session, 700 bills will become law and about 100 of them will have come through our subcommittee and will deal with the Forest Service, the Park Service, or the Bureau of Land Management. We really have two roles in dealing with the three agencies. One is to pass legislation, and the second is oversight. The subcommittee's onsight role is to check up on the agencies and see that the laws that we are passing are being implemented in the way that Congress intended. Since natural fire is a key component in land management in all three agencies, Congressman Vento and the subcommittee have a great interest in how well that program is being implemented. My personal role for this subcommittee is to handle any legislation or any policy issues coming before us that deal with the wilderness system and forests and forestry in general.

I became personally interested in natural fire long before coming to work for Chairman Vento and the subcommittee, because I worked for 18 years for the Forest Service, in three regions of the National Forest System. I had assignments with the Nez Perce National Forest in Idaho, the Wallowa-Whitman National Forest in Oregon, and the Toiyabe National Forest in Nevada. In my early days with the Forest Service, I was a smokechaser and a fire lookout, and so I was heavily involved in the whole fire organization right from the beginning.

My very first job with the Forest Service was at the Black Butte Lookout above the Salmon River Canyon in Idaho. The Forest Service flew me up there in a helicopter with all my food for the summer, and after the helicopter took off, I did not see another person for 3 months, not even in the distance. The Forest Service was nice enough to bring my mail to me once in the course of the summer. The mail package was dropped from an air patrol plane. Unfortunately, it missed the lookout and I watched a summer's accumulation of mail disappear into what is now the Gospel Hump Wilderness. So even that contact with other people was lost.

My first boss at that time in my career was a District Fire Management Officer (in those less-enlightened days he was actually called Fire Control Officer), who happened to be sort of a living legend in that part of Idaho; his name was Ace Barton. I was about 20 years old when I was one of Ace's lookouts and smokechasers.

Ace had a big influence on how I looked at fire and how I looked at the Forest Service and the whole fire organization in natural resource agencies. He was considered to be the finest fire boss the Forest Service had for that very rugged, steep Salmon River and Snake River Canyon country. The whole Hell's Canyon area was part of his territory. But he was so much more than just a firefighter, even though that was his job on paper. He was also the local forest historian.

I remember when the Ranger District decided to throw out all its historic files going way back to 1910. Ace saved them and moved them over to his house until years later the Forest Service decided, well, maybe these are important things to keep. Ace was the first person, or at least one of the first people, in the Forest Service to recognize

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Jim Bradley, Subcommittee on National Parks, Forests, and Public Lands, U.S. House of Representatives, Washington, DC 20515.

that Hell's Canyon was really a unique recreational opportunity and an interpretive opportunity. He had us firefighters out there in what later became the Hell's Canyon National Recreation Area doing interpretive work, teaching the public about the ecology and the natural resources of Hell's Canyon.

Ace also was somewhat of a forest philosopher. I remember him describing to us grunt seasonal firefighters the intricacies of the Forest Service budget process by saying that the way to understand it was to just think of a leaky fire hose. Here in the halls of Congress is the fire hydrant, the source; the nozzle of the fire hose is out there at the Ranger District. The first leak, Ace said, was at the Chief's Office in Washington, DC, and all this money was spewing out of that leak. And then there was another big leak at the Regional Office in Missoula and a lot of money was spewing out there. There was another big leak at the Supervisor's Office in Grangeville. Finally at the Ranger District, a couple of little drops come out of the nozzle.

Ace was more than a firefighter, historian, and philosopher; I think predominately he was a leader. When we would be out doing district work projects like piling brush or burning slash piles, Ace would periodically show up and pick up a tool and work right alongside of us. That kind of thing made him the type of person you would follow anywhere.

Over the years I came to realize that in the fire organizations of the natural resource agencies there were many people like Ace Barton, and there are many people like Ace Barton at this conference. To me, this type of person exemplifies what is best in our natural resource agencies.

I actually became personally involved in natural fire a few years later when I became a wilderness manager in the Selway-Bitterroot Wilderness in Idaho and the Eagle Cap Wilderness in Oregon. I happened to be there right at the time when the Forest Service was creating the very first natural fire plans for wilderness. My role was to help come up with ideas on how we could educate the public on the importance of natural fire. Obviously, a key component of any natural fire program is public education. You cannot have a natural fire program unless the public understands its importance.

I remember we used to go to schools, and we came up with a skit in which the kids would actually reenact a natural fire. We would have kids be the forest and the animals in the forest; one kid would be a lightning bolt that would come streaking down from the sky and strike another kid that was supposed to be a dead snag. All the kids brought scarves that they would pull out of their pockets to be flames. And then after the fire we had kids who would be lodgepole pine cones that would open up and sprout, kids who were new shrubs and shoots, kids who would be elk that would come in and graze on the new browse. The skit was an effective way to teach young people that lightning-caused forest fires are actually part of the wilderness ecosystem.

## PROGRAM IMPORTANCE

There are two basic reasons why natural fire is an important program to Chairman Vento, to the subcommittee, and to many members of Congress. I think the first is that land management policy should be directly tied to science. Land management policy should not be based on what is politically expedient; it should not be based on what is popular. It should be based on good science. This is particularly important to our chairman because Mr. Vento comes from a science background; he once was a science teacher. And natural fire is good science.

Any national park or wilderness area where natural fire for thousands of years has been part of the natural ecosystem that does not have a natural fire program does not have a policy based on correct science. So I think that is the primary reason why we want to see the natural fire programs of the agencies strengthened.

The second basic reason is that Chairman Vento and the subcommittee, as do most American people, dearly love wilderness and they love the National Wilderness Preservation System. This subcommittee is the group that creates wilderness areas. We do not have a true wilderness area without natural fire; wilderness and natural fire go hand-in-hand. Wilderness is so popular in the Country today that we have created over 100 million acres of it and the system is still growing. Every year, Congress designates new wilderness areas, and in almost every wilderness bill Congress designates more wilderness than the agencies recommend. That is a reflection of how popular wilderness is to most Americans. And if we truly love our National Wilderness Preservation System, we must have natural fire out there. Because without natural fire, we do not have a wilderness ecosystem. That is what the Wilderness Act is really all about—preserving the natural ecosystem and letting the natural ecosystem operate; and we must have natural fire to do that. I maintain that the greatest threat to the natural wilderness preservation system today is probably the lack of natural fire. It is far more significant than messy campgrounds or eroding trails or litter or garbage or things that we usually focus on. When we get right down to fundamentally how the ecosystem operates, it is a big threat if we are not allowing fire to operate in the natural ecosystem.

## PROGRAM CONCERNS

So, for these reasons, we are very concerned about the state of the natural fire program today in the land management agencies. We are not satisfied with where it is right now. It is very distressing, for example, that there is less natural fire in parks and wilderness today than there was a few years ago. It has been a declining program. If you look at the statistics of how many natural fires are allowed to burn, at one time the total was 100 natural fires each year in wilderness areas, and now the average is less than 30. There are still too many areas that do not have natural fire plans. Whole Regions of the Forest Service apparently are not doing much of anything in natural fire. Regions 2, 5, 8, and 10, for example, are particularly weak.

But just having a natural fire plan is not good enough. Some areas have natural fire plans approved and in place, but line officers still are not allowing any fires to burn. A classic example of that is the Frank Church-River of No Return Wilderness in Idaho. If there is any place where natural fire should be able to operate, it would be the

Frank Church because it is the largest wilderness area in the lower 48 States. What an opportunity! The wilderness has a natural fire plan. We took an official subcommittee trip out to the Frank Church, and we were told by the wilderness rangers that, although they have a fire plan in place, they are still putting out almost all of the fires that occur there. Well, this is not a natural fire program and this is not the way things should be. And just allowing little fires to burn—that is not right either.

The natural ecosystem for thousands of years had big fires. The vast lodgepole pine forests in Chamberlain Basin in the Frank Church, the lodgepole pine forests in Yellowstone National Park, the great brush fields that created large elk herds in the Selway-Bitterroot Wilderness—those ecosystems were not created by a little 1-acre fire here and a little 1-acre fire there. Fire was part of the natural ecosystem, and those were big fires. We have to allow some big fires to burn as part of the natural fire program.

We think that some land managers are misinterpreting the significance of what happened in 1988 in general and with the Yellowstone fires in particular. To us, what really happened was that millions of people were educated on the role of natural fire. "National Geographic" did articles and there were network news stories, all educating America about natural fire and its place in the ecosystem. So now there are millions of Americans who know that fire is not all bad, that fire does have a positive role to play. They did not know this before 1988. As land managers, we all can capitalize on that and put it to good use.

To us, it all boils down to just old-fashioned gutsiness. It takes a lot of courage to be a land manager. It takes courage to take on a rancher if the range is overgrazed, or to take on a miner if the mining claim is not being rehabilitated. It takes courage to have a natural fire program. So we hope that this meeting in Missoula will create a new dawn for the natural fire program, and that all of you will have the courage to make natural fire have the role it needs to play in park and wilderness ecosystems.

# Evolving Conceptions of Wilderness: Implications for the Management of Fire

George Stankey
Stephen F. McCool

**Abstract**—While the concept of wilderness in the American landscape may be traced to the mid-19th century, it was not until 1964 that formal, Congressional protection began. The resulting National Wilderness Preservation System, encompassing approximately 95 million acres, is not only much larger than originally envisioned but is embedded in a complex and everchanging social-cultural milieu. In the 19th century, wilderness was pretty but something that was not engaged directly. In the mid-20th century, wilderness was still thought to be pretty, but as a backdrop for primitive recreation. As we prepare to enter the 21st century, we now see wilderness as a sometimes ugly and dangerous place, a location where the power of natural processes dominates the landscape. Such changing definitions of wilderness hold important implications for management of fire, for the appropriateness of any management technique is determined by social definitions of the resource and how to protect it. Management of fire represents a class of complex environmental problems confronting postindustrial America where the needs of an administrative-technocratic state to solve the problem clash with the increased interest in public access to government decision making. An interactive approach to decision making, where fire managers work with the public to determine appropriate and effective management programs, ensures that important questions are asked and the necessary political support for implementation is achieved.

Wilderness and fire join two of the most evocative terms in natural resource management. Combined, they raise images of fear and joy, beauty and horror, disaster and triumph, even life and death, simultaneously. Thus, in the search for effective wilderness fire management strategies, our path of inquiry must transcend the formidable technical difficulties of fire science to embrace the complex social and philosophical aspects these concepts symbolize.

In this paper we explore the implications of these complexities for those charged with the management of wilderness. We argue that there exist patterns and structure in the relationship between society and wilderness that hold promise and potential for building feasible and implementable management programs. First, we examine the historical and philosophical roots of the wilderness concept. Then, we sketch the evolution of institutional structures for wilderness protection, including a brief summary of the growth and status of wilderness reserves and their use. We then turn to the development of a management framework that can join the evolving social appraisal of wilderness with the need to formulate appropriate and practical fire management strategies in wilderness.

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## WILDERNESS: FROM REPULSION TO RESOURCE

When Zimmerman (1951) wrote "Resources are not, they become," he reminded us that resources derive from cultural appraisal and constitute a social construct, rather than some physical-biological reality. Such a process of social evaluation is both spatially and temporally dynamic; what society defines as a resource is constantly changing in response to changing technology, markets, and preferences. Thus, for example, we see Pacific yew shift from weed to wonder drug.

The concept of wilderness has undergone similar evolution (Nash 1982; Stankey and Schreyer 1987). For example, the concept of wilderness appears in the Old Testament, often as a synonym for the desert, a place alien to human use and occupancy. Biblical injunctions to make the desert "blossom as the rose" and to "multiply and replenish the earth, and to subdue it" provided an early and enduring imperative from which society's drive to conquer the wilderness (to turn it into something useful) has been sustained.

However, the Biblical depiction of wilderness is not uniformly one in which it is subjugated to the dominion of society. Wilderness also served as a place where one could commune with God, a place where the absence of civilization was an essential attribute in preparation for encountering the Lord. In this sense we can discern one of the enduring attributes characterizing the relationship of society to wilderness; the notion of *ambivalence*. Through history, our relationship to wilderness has been one of "love-hate"; the imperatives to subdue wilderness tempered by concerns with retaining some vestige of the natural world from which we evolved and with which we continue to feel a connection.

A second attribute characterizing the relationship of society to wilderness is the notion of *irony*. Only when virtual dominance over wilderness is achieved does society come to value it and move to protect it. Thus, ironically, scarcity is a necessary condition fostering wilderness protection (McCloskey 1964). It was only 30 years after the 1890 census signalled closure of the American frontier that Forest Service officials initiated the first national inventory of remaining wilderness; it revealed that

the 2-billion-acre wilderness estate that greeted European settlers had shrunk by over 95 percent (ORRRC 1962). Such a realization helped prompt the first systematic wilderness protection program shortly thereafter.

The third attribute of the relationship between society and wilderness is that of *evolving conceptions*. Earlier, we noted the role of social appraisal in the definition of a resource. Throughout human history, various wilderness conceptions have appeared, then receded to be replaced by new views. We have seen wilderness shift from the realm of evil, foreboding, and danger to the place of hope, thrill, and discovery. As the conceptions of wilderness have changed, so too have the social meanings such areas hold and the implications for how we manage them.

Nash (1985), for instance, talks of the "Old Wilderness"; places of murmuring pines and forest primeval. This was the image of wilderness that dominated perhaps a century ago. Highly romantic, consistently beautiful, it depicted nature as a static representation of what people thought it *should* look like. Indeed, wilderness was almost entirely a representational construct; something which we observed but did not engage directly. There was no place for danger or ugliness in this wilderness.

Another conception of wilderness gained attention in the late 1950's and 1960's, fostering a view of dispersed and undeveloped recreation areas. As with the "Old Wilderness," such areas were scenically attractive, but contrasted with this earlier view, society directly engaged this wilderness (McCool 1983). This was the era of rapid growth in recreational use of wilderness. For example, in the period 1965 to 1980, recreational use of National Forest Wilderness increased 82 percent (Petersen 1981).

An important aspect of this conception of wilderness was the management emphasis it engendered. Appropriate management entailed steps that facilitated human use and protected scenic quality; like the "Old Wilderness," there was little room for the ugly or dangerous.

A third conception of wilderness is now unfolding. It represents a major departure from earlier notions. At its root lies the notion of natural processes, of allowing the "natural" ebb and flow of nature to operate freely. It is a response to both the spirit and letter of the Wilderness Act, which defines wilderness as "where the earth and its community of life are *untrammeled* by man" (emphasis added). This evolving notion of wilderness has received attention from McCloskey (1990), who observes that most of the "biocentric" reasons for valuing wilderness are of recent origin (in the last 30 years) whereas most of the "anthropocentric" reasons date to the 19th century. The "New Wilderness" (Nash 1985) represented by this emerging conception radically departs from earlier ideas and carries major implications for wilderness management in general and wilderness fire in particular.

## GROWTH OF WILDERNESS AND ITS USE

Formal, explicit protection of wilderness in the United States is a relatively recent phenomenon. Calls for the protection of wilderness can be traced to the early 1800's (for example, Catlin and Thoreau), but had little impact upon public policy. Even events such as the reservation of Yellowstone and Yosemite had little to do with wilderness; they reflected concern with issues related to the relationship between public and private control (Nash 1985).

It was only following the first national inventory of wilderness lands under National Forest administration in 1926 that concern with the systematic protection of such areas received attention. This culminated in 1929 with the L-20 Regulation, creating the Primitive Areas System. However, even this action has to be interpreted in light of concerns for controls over haphazard development of National Forest lands (ORRRC 1962). The L-20 Regulation was seen as temporary and its role in codifying wilderness protection was secondary to its role as a general land-use control. Nevertheless, during its 10-year life, the regulation led to the protection of 72 areas containing 13.5 million acres.

The shortcomings of the L-20 Regulation, deriving from the lack of permanence, its permissiveness, and particularly its lack of clear purpose, were highlighted by Bob Marshall, who came to the Forest Service in 1937 from the Office of Indian Affairs. In 1939, the L-20 Regulation was supplanted by a new series of administrative regulations reflecting Marshall's influence, the U-Regulations.

These new regulations brought a sharpened sense of purpose to wilderness protection, focused particularly on the need to maintain wilderness as a distinctive contrast to the developed landscape, and emphasized its value to society as a source of historical, educational, and recreational benefits. It called for review of the existing primitive areas and their reclassification into one of three land-use designations: *Wilderness Areas*, containing at least 100,000 acres and requiring Secretary of Agriculture approval for their establishment, modification, or elimination; *Wild Areas*, containing between 5,000 and 100,000 acres and with Chief of the Forest Service approval required for any change; and *Roadless Areas*, to be managed primarily for recreational use "substantially in their natural condition."

Although the U-Regulations contained significant and progressive changes for wilderness protection, their impact was diminished by the untimely death of Marshall in 1939, followed by the outbreak of World War II. As a result, little progress in the review and reclassification of primitive areas took place; by the late 1940's, only 2 million acres had been reclassified (Roth 1984). The sluggish progress troubled wilderness proponents; while the review process stagnated, many areas containing wilderness values were lost as the period of postwar prosperity generated new demands upon America's natural resources. By the late 1940's and early 1950's, there were growing pressures for a statutory system of wilderness protection, similar to that for the National Parks (McArdle 1975).

The idea of legal protection for wilderness was not new; H. H. Chapman, professor of forestry at Yale University, had suggested such an idea in the 1930's (Chapman 1938) as had Secretary of the Interior Harold Ickes (MackIntosh 1985). However, whereas in the 1930's the necessary social and political support and will were not sufficient to effect such a change, by the mid-1950's this had changed. Growing economic and social security, heightened awareness of the diminishing wilderness estate, and the development of effective political support provided fertile ground for a major reformation in wilderness protection.

Introduced in 1956, the Wilderness Act became law in 1964. It represented a fundamental reformation in the way wilderness lands were to be protected. Up to this time, wilderness protection had been solely a function of administrative action; hence, could be easily changed. Now, wilderness enjoyed the protection of Federal law.

The Wilderness Act also led to the consideration of a much wider range of areas than was originally envisioned. This was particularly the case with regard to wilderness in the eastern United States. Dissatisfaction with the reluctance of the Forest Service to make any recommendations for wilderness in this region led to passage of the so-called "Eastern Wilderness Act" in 1975. The significance of this event lies more in its reflection of the evolving conception of wilderness to which we referred earlier than to the number of areas or acres involved. It constituted a statement by society that the wilderness resource was to be defined differently than how wilderness managers might.

The growth of wilderness from 1964 has been steady, at times spectacularly rapid. Today, over 90 million acres are in the National Wilderness Preservation System (NWPS) (table 1). However, the growth of the NWPS must also be seen as representing the diffusion of a concept across the Nation. Although located predominantly in the western and Rocky Mountain regions, the system is virtually nationwide (only six States do not have a wilderness located in them; table 2).

This geographic dispersion of the NWPS, as well as the absolute growth it has experienced, pose what Allen and Gould (1986) have called "wicked" problems for managers and society alike. The rapid growth has outpaced our ability to assess and understand the ecological conditions and processes that characterize these areas. Similarly, the rapid spread of the system has resulted in its establishment in a diversity of cultural settings. Our understanding of the interaction between the varying social perceptions and the biophysical character of the land, critical to effective management, is all but nonexistent. We understand little, for example, of the benefits each of the differing social contexts attribute to wilderness or of the normative standards of appropriateness for specific management techniques in each context.

This issue is confounded by a growing recognition of a broader range of values provided by wilderness. Despite a general appreciation that wilderness provides a variety of values and benefits to society, such as educational, scientific, and historical; in fact, wildernesses have long been viewed as primarily dispersed recreation areas. Burgeoning recreational use levels, especially during the 1960's, helped sustain this view. Annual growth rates often exceeded 10 percent and, coupled with the rapid growth in the number of areas in the NWPS, recreation use appeared to be skyrocketing. Moreover, such use brought a host of problems with which managers were overwhelmed—trail and campsite impacts, littering, crowding, etc.

**Table 1**—Distribution of National Wilderness Preservation System among management agencies (1992)

| Agency | Acres millions | Percent of system |
|---|---|---|
| Forest Service | 34.0 | 36 |
| National Park Service | 39.1 | 41 |
| Fish and Wildlife Service | 20.7 | 22 |
| Bureau of Land Management | 1.6 | 1 |
| Total | 95.4 | 100 |

**Table 2**—Distribution of National Wilderness Preservation System and U.S. population by region (1992)[1]

| Region | Percent of system | Percent of population |
|---|---|---|
| Northeast | 1 | 21 |
| Southeast | 2.5 | 23 |
| Midwest | 2.5 | 36 |
| Intermountain | 20 | 5 |
| Pacific | 75 | 14 |

[1]Northeast region consists of the States of ME, NH, VT, RI, CT, NY, NJ, and PA; Southeast region consists of the States of DE, MD, VA, WV, KY, TN, AL, and MS; Midwest region consists of the States of OH, IN, IL, MI, WI, MN, IA, MO, ND, SD, NE, KS, AR, OK, LA, and TX; Intermountain region consists of the States of MT, ID, WY, CO, and NM; Pacific region consists of the States of OR, WA, CA, HI, and AK.

Recreation use remains important, both in terms of being a source of benefits to society and as a source of impact upon wilderness. Recently, however, there is growing appreciation for other values—scientific, ecological, spiritual, subsistence (Reed and others 1989). Realization of these values and the implementation of management programs to ensure the capacity of wilderness to perpetuate them will require a new relationship between wilderness managers and society. The restoration of natural processes, particularly fire, which the idea of the "New Wilderness" (Nash 1985) calls for, raises images of a wild, dangerous, and at times, ugly setting. As the Yellowstone fires of 1988 reminded us, public perceptions still harbor a view of fire as uncontrollable and destructive rather than as a predictable and essential component of natural ecosystems. While managers and researchers might argue that this is legally what wilderness was meant to be (a place where natural processes dominate), the potential conflict between such a conception and that held by a diverse constituency, distributed across a range of biophysical and cultural contexts, calls for new approaches for decision making.

This conflict cannot be resolved simply by bromides about "educating the public." Although wilderness management occurs within a centralized and hierarchical organizational structure that prescribes normative standards for decision making, in reality it is at the local level that management actions occur and it is at this level that actions have specific consequences. For example, national policies to restore fire to a "more natural role" can result in impacts on recreation users (for example, the loss of a favorite camping spot) and local communities (for example, air pollution from fires). In such a situation, the capacity for effective implementation is compromised.

What structures and processes for decision making might be instituted to deal with this dilemma?

## FACING THE QUANDARY

The issue of wilderness fire management represents a microcosm of a major issue facing modern society: how does society make "ecologically rational" decisions that require technically sophisticated levels of knowledge and understanding and at the same time protect democratic principles that ensure openness and the right of the citizenry to influence decisions whose consequences impact them? This apparent dilemma has been described as a major quandary facing modern society (Pierce and others 1992).

As the environmental management problems confronting society have grown in complexity and significance, we have relied on the centralized administrative state to provide the necessary technocratic structure to cope with these issues. Indeed, there is a fundamental presumption that such structures are essential in order to deal with these complex issues and that efforts to be more open to democratic decision making and public scrutiny only confound our ability to deal effectively with them; "Democracy itself seems somehow at odds with proper environmental management" (Paehlke and Torgerson 1990).

However, such a view fails to recognize the underlying political nature of resource management; that is, it is an activity engaged in the production and distribution of values, be they commodity, amenity, scientific, etc. As we have suggested, the changing and diversifying conceptions of wilderness have outpaced the capacity of management institutions to respond effectively. These changes are matched by growing demands for greater democratization and openness in decision making; from the popular literature (*Megatrends, The Third Wave*) to the more scholarly discussions of Post-Materialism (Inglehart 1990) and the New Environmental Paradigm (Dunlap and VanLiere 1978), we are reminded that major changes in the nature of the goods and services sought by society as well as the institutional structures and processes for achieving them are under way.

What are the implications of these changes for wilderness fire managers?

In a recent book, pollster Daniel Yankelovich (1990), addresses the dilemma of linking democratic principles to technically complex issues. The problem, he relates, is how one promotes *public judgment* as opposed to *public opinion*; that is, how can we facilitate the formation of judgments that reflect an understanding of the consequences and implications of a position as opposed to simply an opinion, which is often fickle and superficial? Yankelovich suggests three stages to such a process: (1) *raising consciousness*, where a sense of awareness and appreciation for what's at stake develops; (2) *working through* the issue, where society has the opportunity to consider the questions of consequences and implications, costs and benefits, winners and losers, etc. Society must also deal with barriers to "working through," including differing values, conflicts among experts, and insufficient/inadequate choices; and (3) *resolution*, where society comes to understand and accept where it stands cognitively, emotionally, and morally.

Yankelovich observes that the media play a significant role in raising consciousness. Resolution is implemented by a variety of laws and administrative policies. However, when we consider the "working through" phase, he finds little institutional capacity. Where, as well as how, do we create the forums in which a deliberative, nonadversarial discussion of subjects that are both technically as well as culturally complex can occur?

## ALTERNATIVE MANAGEMENT STANCES FOR "WORKING THROUGH"

What are the alternative stances a management institution might adopt as it attempts to resolve the quandary of bridging technically complex issues with the demands for democratic decision making principles? Three basic structures seem possible.

First, managers could adopt a *reactive* stance. This would involve "putting right" a state of affairs that has already gone wrong or responding to others' proposals for change rather than initiating one's own (Trist 1976). This is basically a defensive posture; unfortunately, it probably describes the current reality.

Second, we could promote a *proactive* stance. Proactive planning involves taking an active role in bringing about a willed future choice chosen as a desired path (Trist 1976). There is much interest in being proactive, but while it has the potential of changing the customary defensive posture in which resource management agencies find themselves today, it also has drawbacks, largely related to the potential for supplanting the public's prescriptive role in defining desired futures.

Third, management institutions can work toward creating an *interactive* relationship with stakeholders. In this stance, the planner engages directly with stakeholders to mobilize support, build consensus, find acceptable solutions, and secure implementation (Lang 1990). The interactive stance is not without problems, but in our judgment, it represents the most viable and politically acceptable alternative; we also believe there are effective means of dealing with its shortcomings.

## AN INTERACTIVE APPROACH TO WILDERNESS FIRE MANAGEMENT

An interactive approach to management embraces a number of discursive approaches, such as participatory management, mediation, and negotiation. Such approaches possess important qualities lacking in other management approaches.

First, they represent an important means of tapping into the evolving social/cultural values and meanings of wilderness. As we have discussed, such social appraisals are constantly in flux, and with differing conceptions different management implications emerge: "To manage wilderness well, one must understand why people want to have wilderness and what they are seeking there" (McCloskey 1990).

Second, the interactive stance heightens the likelihood that the inquiry process that underlies any management program will address the right questions. Following on our earlier discussion, if we fail to discern the meaning and importance society attributes to wilderness, our capacity to address pertinent issues, questions, and concerns is compromised. In its stead, traditional technocratic orientations can lead to a preoccupation with analyses that might have little to do with society's concerns; as Socolow has observed "analyses are not about what most people care about" (1976). In such cases, technical analyses, data manipulation, and concerns with scientific issues can dominate organizational attention, failing to address the key questions that underlie public concern.

Third, interactive settings promote mutual learning and can engender broadened concepts of relevant knowledge (Friedmann 1987). This aspect underlies a fundamental premise of the interactive stance; all stakeholders bring relevant knowledge to the discussions to define resolution (Yankelovich 1990) or societal direction (Friedmann 1987). Typically, conventional planning restricts the provision of knowledge to the technical elite. However, "in practice, the positions and interests of central organizational actors screen out the perception of relevant features of situations and problems. Conventional orientations are thus limited, ironically, in the very realm they take to be their own: knowledge. In particular, their sources of knowledge are inadequate to problems arising from new, complex, and dynamic situations" (Paehlke and Torgerson 1990).

This aspect of interactive planning is also necessary to facilitate the "working through" phase, the crucial feature of which is to help stakeholders gain a sense of the consequences and implications of their positions; while "there are no guarantees that people will make wise decisions... they have an incentive to do so; they must live with the consequences" (Paehlke 1990).

## BARRIERS TO INTERACTIVE PLANNING

Although interactive approaches to planning are gaining attention, there still exist formidable barriers. First, it is common to perceive such approaches as constituting a loss of control, power, and authority; a not altogether cynical view is that "government bureaucrat's aim is not to hand over control, but to maximize it" (Schwarz and Thompson 1990). However, if one accepts the view of resource management as fundamentally political, the real question here is how can the management bureaucracies maintain legal power when their behavior is perceived as inappropriate or even illegitimate by the body politic, which holds political power? The answer, it seems to us, is that they cannot; in an ironical sense, power sharing by resource managers may be the only means they have of retaining their legal power.

Second, there are concerns that this approach somehow "dilutes" the quality of resulting decisions, in part because the public is incapable of understanding the technical complexity of the issues. Again, there is little evidence to support this view; in fact, there are a number of specific resource issues in which the presence of early, continuing, and substantive public participation *enhanced*, rather than detracted from, the technical quality of resulting decisions (for example, the Alaska pipeline).

Third, there is concern that public concerns will only address "cosmetic" or "amenity" issues, such as concerns with scenic impacts or recreation, or will be self-centered (the NIMBY or LULU syndrome). Again, evidence is to the contrary; Fortmann and Kusel (1990), in a study of public participation in California, reported that dominant public concerns addressed such issues as biodiversity, soil erosion, and long-term site productivity.

Finally, the interactive stance is criticized as being a guarantee of chaos and disorder. In such a view, it is not that such an approach is less effective, but that it is practically impossible. But in fact, what is involved is not a loss of order, but the enactment of a new form of order: "We are never confronted with order as such, but always with a particular order—and any particular order is *bound up with particular interests* (emphasis added). ...This points to the hidden political dimension contained in claims that any particular order is administratively necessary" (Paehlke and Torgerson 1990).

## CONCLUSIONS

In a critique of National Forest planning, Wondolleck (1988) observed that it is not that the agency is unable to make decisions, but that it can't make "decisive decisions"; in short, it is unable to implement what it proposes. Its inability to do so has little to do with the technical capacity of its programs; it has everything to do with the failure to see its actions as political.

The reintroduction of fire into wilderness ecosystems can only be successfully implemented if community understanding and support exist. The image of fire as a destructive, alien force is powerful, exacerbated by the speed and vividness of modern communications and, not incidentally, by our own efforts over the past 70 years to promote antifire behavior among the public. The emerging conception of wilderness as the setting where nature's rules take predominance provides an opportunity for communicating a new message to the public, but it will require equally dramatic changes in the nature of our decision-making apparatus and processes.

While there are significant barriers, we conclude that the only practical method to tap into emerging concepts of wilderness is through an interactive method of decision making. This method, as opposed to reactive and proactive alternatives, allows fire and wilderness managers to continually assess these changes in social preferences as well as learning and testing new approaches to and concepts of management. Again, interactive approaches ensure that managers are pursuing the right questions, the questions of social relevancy and appropriateness, not ones of purely professional interest.

Interactive approaches also allow the public to "work through" a complex environmental issue so that the resolution is an informed one. Working through creates opportunities for ownership in the resolution, setting the stage for consensus and effective implementation. By interacting with the affected publics, managers ensure that

technical information and knowledge is incorporated into public resolution and policy.

Understanding the inherent political nature of natural resources management does not cripple decision making; rather it allows managers to explore alternative models of planning and engaging with the social-political context to enhance public knowledge and support of complex issues. The irony is that if fire managers resist such engagements on the grounds that the issues are too complex for the public to understand the capacity to meet the goal of restoring natural ecological conditions and processes in wilderness will be severely compromised if not thwarted altogether. Acknowledging the legitimacy of interactive decisions will help fire managers in their quest for authentic natural processes in wilderness.

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# Vestal Fires and Virgin Lands: a Reburn

**Stephen J. Pyne**

**Abstract**—What we call wilderness fire is the merger, collision, mixture, alliance, confrontation, and altogether curious and perplexing association of two very different traditions. One is nature preservation, particularly as expressed in wilderness; the other, anthropogenic fire. Each is itself a hybrid of the natural and the cultural. Each belongs to a tradition with its own autonomous history. For a period of time, however, these two phenomena converged, like continents colliding, and those cultural tectonics had powerful consequences for both wilderness and fire management. Now they are rifting apart.

They came together, fire and wilderness, like steel on flint and threw sparks that kindled a special kind of flame.

The belief grew that Americans had a unique relationship to nature, that wilderness was something vital to our national experience, that natural areas ought to be preserved to express those values and bolster that identity. With the Leopold Report (1963) and the Wilderness Act (1964) beliefs became matters of policy, ideas evolved into an ideology, and wilderness claimed the high ground of a new environmentalism, a shot of America heard round the world. Inevitably changes in how Americans managed lands affected how they managed fire. By 1970 the question of wilderness fire began to dominate the American fire establishment, a reign that flourished until its self-immolation, like some wildland Wall Street, in the Yellowstone conflagrations of 1988.

In the beginning the issues seemed obvious, and the solutions self-evident. It was held that fire is a wholly natural process and wilderness a completely natural environment; that the two are intrinsically compatible, and have been for geologic eons; that the question of fire management was simply to remove the impediments, all anthropogenic, that inhibited their natural association. To establish wilderness it was only necessary to abolish the human presence, and to promote wilderness fire it only remained to eliminate the intrusions of human fire practices, particularly the obnoxious conduct of high-technology fire suppression. Wilderness fire management was simply a process of restoration. Remove the intrusions and wilderness would thrive; free-burning fire would reestablish its symbiosis with the wild, like lianas intertwining with tropical trees. In this model of nature's economy untrammeled natural processes, like Adam Smith's invisible hand, would seek out an ideal equilibrium, balancing supply and demand, fuel and fire. By removing ourselves we would allow nature to preserve a vestal fire on America's virgin lands.

The reality has been more complicated. With wilderness fire we are not dealing with a natural phenomenon and a natural environment but with two hybrids of nature and culture. We are not simply putting a natural process back into a natural landscape but trying to reconcile one hybrid, fire, with another hybrid, wilderness. Neither is a fixed idea or set of practices. Both have their own complex and independent histories. They had not been created together, or coevolved over millennia; they were thrown together, violently, like continental plates ramming into one another. That the process of harmonizing the two should be perplexing—institutionally, intellectually, and operationally—goes without saying. Theirs was a shotgun wedding. Separation was inevitable.

Their encounter not only reshaped American cultural geography but themselves. Fire demonstrated the fallacies of laissez-faire wilderness management, exposed the paradoxes of banishing humans from nature, and revealed the way in which wilderness was an artifact of American society. For its part, wilderness compelled a national obsession with fire control to confront its absurdities, to admit its ecological and economic costs, and to reaffirm that its purpose is to serve land management, not itself.

Their collective consequences—call it wilderness fire—exceeded their individual effects. But what wilderness fire announced it could not answer. While it forced its originating traditions to question their ends and means, what began with philosophical conviction has concluded with uncertainty; early accomplishments have become future conundrums. It is no longer clear how to rekindle the vestal flame without burning down the sacred grove. And it is not obvious that American society cares enough to commit special attention to the enterprise.

## WILDERNESS: THE CONCEPT

Wilderness is not a state of nature or a universal concept in human societies. Rather, modern-day wilderness is an intellectual construction, and wilderness sites are cultural artifacts, the product of a constantly evolving state of mind interacting with a constantly changing natural environment. It is increasingly clear that wilderness is only one of many forms of nature preservation, that its particular expression in America shows strong cultural biases, that wilderness is, in fact, a peculiar creation of a peculiar people at a peculiar time in their national history. Pretending otherwise is itself a cultural decision—or an exercise in collective self-delusion.

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Well before it acquired legislative definition, wilderness had become a fundamental part of a national creation myth—in fact, much of the urgency and sense of moral fervor behind wilderness preservation derived precisely because of this association. America's virgin lands took the place of those kinds of cultural monuments that Europeans used to express their national character. Americans lacked cathedrals like Mont St. Michel, Roman coliseums, Parthenons; but they had Niagara, Grand Canyon, and giant sequoias to serve as surrogates. The encounter between Americans and those natural wonders became our "Iliad," our "Aeneid," our "Gilgamesh." Like them the story defined an American identity and a national destiny. Like them, too, the story is a tragedy in that the founding hero must leave or die; the pioneer destroys the conditions that make pioneering possible.

This notion represents the latest installment in a venerable intellectual enterprise, the encounter of Old World ideas with New World environments. As they pondered these exotic peoples and places—outside the domain of ancient philosophers, beyond Ptolemy's *mappa mundi*, indifferent to the genealogies of the Old Testament—many savants began to imagine concepts, intellectual constructions, by which to exploit the apparent discrepancies between the two worlds in order to advance assorted political or cultural purposes. The Noble Savage, the Forest Primeval, the Virgin Land, the Untrammeled Wilderness—all are ultimately parables, moral templates, with which to criticize the decadent civilization of the Old World and to exhort the New World to do better. They represent myths of a past Golden Age of natural and moral order, relocated from a Mediterranean Eden to the American Wilderness. Their population is prelapsarian. Their promise is that America is a chosen land, spared the ravages of the Fall, closer to the Creator. Such ideas are philosophical paradigms and literary conventions, however, not reports on the natural environment.

To this basic formula other values have been grafted. That the land possesses information vital to science; that it preserves biodiversity and affirms biocentric values; that it offers the opportunity to reexperience the awe of western explorers and the hardihood of pioneers; that it is a part of our landed heritage, the raw stuff out of which our civilization has evolved—all presuppose the values and institutions of American civilization; none are inherent in the landscape itself. American wilderness and its meaning were shaped, and continue to be shaped, by the society that defines them. Yet by configuring our conception of wilderness, even to the point of fixing it in legal language, these ideas have assumed the status of management goals. What began as a state of mind has reified into a putative state of nature. Almost all of the paradoxes of wilderness fire derive from this bold, flawed translation.

But it is important to remember that wilderness is only one of many forms of nature protection, that the preservation of the natural world has extended also to endangered species and their habitats, to biosphere reserves established as scientific laboratories, to a vast array of reservations around the world—from Russian *zapovedniks* to African game preserves to the sacred groves of Mount Athos—for which wilderness, as Americans understand that concept, is more or less irrelevant. These sites have sought to define a special relationship between humans and nature, but they do so as an expression of different social values, for which the creation story underlying American wilderness is as indifferent a guide as the "Ramayana" would be for managing the Yosemite or the "Kalevala" for the mountains of the Selway-Bitterroot.

What was a strength has now become a weakness. This, the 30th anniversary of the Leopold Report, is also the 100th anniversary of Frederick Jackson Turner's celebrated essay, "On the Significance of the Frontier in American History," delivered at the Columbian Exposition, which convened in Chicago to celebrate 400 years of European discovery. Today both the reputation of Columbus and the western saga lie in tatters. Discovery has been redefined as Encounter, suggesting a greater equivalency between Europeans and Amerindians; the Winning of the West has become a grimy Legacy of Conquest, with the frontier only an exercise in ironic imperialism and environmental dislocation; the politics and scholarship of multiculturalism has, in brief, shredded the intellectual and mythic story behind the wilderness ethos. Shane won't be coming back. A lot of professional intellectuals regret that he came in the first place. The contemporary wilderness mosaic must somehow express ethnicity and gender as much as forest age classes and precolumbian biomes.

This deconstruction takes many forms inspired by many motives, not least its growing irrelevance to a population swollen by immigrants from places outside Europe and the cultural reprivileging of peoples (such as African-Americans and American Indians) who stand outside it or who were its putative victims. The aspect most pertinent to fire management concerns the place of precolumbian peoples, those who were here before the wilderness. It is one thing if Americans, operating out of European traditions, choose to declare themselves unnatural and deny themselves access to wilderness sites; it is another altogether to extend that declaration to America's indigenes. Even a decade ago the question of "Indian burning" was a quaint appendix to fire management. As "native peoples" American Indians were either part of the natural scene or were perceived as unable or unwilling to influence it in any serious way. That Indians burned merely meant that fire suppression was wrong, and hence the effort to "restore" fire was appropriate. Their fires, like the Indians themselves, simply merged into the landscape. They were part of the natural order, nothing less and nothing more.

## WILDERNESS: THE CRITIQUE

This of course is absurd, and its ecological and historical absurdity has long compromised practical management. More recently the cultural, philosophical, and moral premises that underscore wilderness management have become equally untenable. They can no longer be ignored.

The absurdity begins with the land. How can a park like Yellowstone, for example, argue for reintroducing wolves because they are a part of the "original" ecosystem and yet deny the most prominent predator of all, *Homo sapiens*? How can anyone dismiss anthropogenic fire as inconsequential or indistinguishable from lightning fire? Biotas are adapted not just to fire but to fire regimes, and all the regimes of Holocene America have emerged within the

context of anthropogenic burning or that negotiated matrix between lightning and humans. Eliminating that fire does not restore wilderness to a Golden Age but fashions an environment that, in all probability, has never before existed. Anthropogenic fire was as vital a process as floods, droughts, and epidemics in shaping precolumbian landscapes. That process cannot be dismissed without disrupting the systems under protection. This is eminently obvious for biomes like the tallgrass prairie; but in different ways it is true everywhere, from the Brazilian *cerrado* to the Swedish *heden* to the French *maquis*. Only in America is the role of indigenous peoples regarded as trivial or irrelevant. That is a judgment rendered on philosophical and political, not ecological, grounds.

Instead natural areas must grant to humans ecological roles commensurate with their numbers and powers, allowing them biotic citizenship as fully as bison, elk, and coyotes. Surely humans, even hunters and gatherers who after all preyed on wildlife, fished, foraged for grasses, nuts, fruits, and tubers, and who of course set fires—much more those peoples who cleared, slashed and burned, and herded livestock—had as much ecological impact as snail darters, pupfish, spotted owls, and blackfooted ferrets. How, on biological grounds, can those consequences be dismissed? Or if they can be excluded as ecologically trivial, then why not those endangered others?

The dismissal is no less absurd historically. American explorers did not encounter a raw nature, as later explorers would on the Antarctic ice sheets or the Viking spaceprobes would on sandy Mars; they encountered a landscape already populated and, within the limits allowed by their technology, remade to better suit those inhabitants. Everywhere people mediated the encounter with the wild. Frontiersmen relied on Indian guides, learned Indian skills, and often took Indian wives. They seized Indian fields for their own, and grazed livestock where Indians hunted wildlife. To the dangers posed by grizzlies, blizzards, and prairie fires, they faced the much greater hazards of hostile humans. Successful frontiersmen learned to live with the indigenes or to live like them or to overcome them. Those were the vital wilderness survival skills.

Yet all this is gone from today's wilderness. Recreating the vegetation at the time of European discovery or preserving select natural processes does not recreate the historic wilderness experience because the most critical element, the encounter with humans, many hostile, all alien, is gone. It was those native peoples who made the wilderness "wild," which is to say, exotic, unpredictable, dangerous, exciting, and wondrous to those for whom it was not already home. Similarly dismissing the things those peoples did, including burning, only sustains a landscape that is historically incomplete. But to accept as valid those indigenous peoples only leads to other questions. One must ask which native practices to preserve, from which native people, and from which times in their complex histories? The past is multiple, and history, a negotiated compromise between the records of those pasts and the needs of the present.

Not least, the calculated dismissal of precolumbian fire is increasingly absurd on social and political grounds as well. Multiculturalism simply won't allow that pre-European landscape to be emptied. Stripping American Indians of the power to shape their environment with fire is tantamount to dismissing their humanity. Our capacity to manipulate fire is a species monopoly, unique to humans but also universal to all humans. Deny someone the right to fire and you deny them that status.

There is more at issue, however, than crude political correctness. By forcing a reexamination of the creation myth behind wilderness, multiculturalism has compelled American society to reconstruct the moral universe within which it manages wilderness. The decisions we make regarding fire practices are, inescapably, moral acts, which is to say they emanate from ideas about who we are and how we should behave. This influences even the way we manage fire because, although as a species we are genetically equipped to handle fire, we do not come programmed knowing how to use it. Decisions about what kind of fire to apply and withhold have to rely on a larger cultural context, and they have to seek some basis for legitimacy. Along with the power that came with fire, humanity assumed a responsibility to use it and to justify that use.

Initially it was a sufficient principle of wilderness and park management to renounce as inappropriate certain practices, particularly when they relied on guns or mechanization, the wholesale slaughter of elk or fireline construction with bulldozers, for example. But long-term administration demanded some positive goal as well. To this a wilderness ideology proposed a simple solution. The "state of nature" conveyed a moral order, one ultimately descended from Nature's God. Wild nature—that is nature unpolluted by humans—was the purest expression of that natural order, and hence the highest moral condition. The state of nature might consist of biotic objects and landscapes, arranged according to some pattern, or it might exist as an ensemble of processes. Typically this condition existed in the past, but it might also be recreated in the future. Efforts to preserve or restore wilderness thus were sanctioned by an order of Nature that transcended humanity and that located the source of judgment outside human society.

Instead, I would argue, those decisions are our own. We occupy an existential Earth that can assume many forms, has known many pasts, and can evolve toward many futures, none of which is privileged. Likewise human fire practices are profoundly relative, and their suitability depends on criteria that are as much a part of our cultural context as they are of the natural landscape. Removing anthropogenic fire from legal wilderness does not create precolumbian landscapes. More probably it helps degrade those biotas. To claim, as some have, that nature is amoral does not change the fact that, for humans, how to act toward wilderness (or any other land) must originate from human consciousness and human will. The decision to allow a patch of land to exist "untrammeled" by humans is not an instinctive part of our genetic code. It is rather a deliberate decision made by a particular society. It is part of the peculiar power of fire that it exposes these circumstances, like a torch thrust into a dark room.

If humans cannot be excluded from wilderness on ecological grounds, if there is no historical validity to the expulsion of precolumbian peoples, if the philosophical arguments for a state of nature are specious, if social and political pressures for multiculturalism are redefining the national character and its expression in nature preservation, if the moral privilege claimed by laissez-faire wilderness management

is untenable, then it would seem that the question of wilderness fire is at best muddled, and at worst cynical. One might satirize National Park Service goals, in particular, for their uncanny fidelity to the Prime Directive issued to the Starship Enterprise. (Curiously both began their careers in the same year, 1967.) The quirky quality of American wilderness management might aptly be characterized as Starfleet's mission to Earth.

(Like the Prime Directive those guidelines encourage exploration, discovery, science, and adventure but do so without any of the moral ambiguities or practical quandaries that real-world encounters bring. It is somehow possible to engage other worlds and lifeforms without interfering with their internal development. It is possible to observe the dynamics of Yellowstone's fauna or the mosaics of the Bob Marshall's forests without pollution. And like the Prime Directive, which allows for selective intervention when the "natural" evolution of a planet or people has been distorted because of prior contact, so wilderness managers have argued for manipulation in the name of restoring the scene to an earlier, precontact state, rooting out prior contamination by sheepherders, CCC, or fire control.

But Starfleet outfits its ships with warp drive, transporters, and universal translators; the National Park Service had portable radios, rusty McLeods, and drip torches. Wilderness managers could not both be present and not be present. Of course they had to intervene. Fire managers can't hide behind holographic projections or vanish in a transporter's glow. Whether or not we choose to stand outside those lands we call "natural," there is no way we can stand outside ourselves.)

Of course humans can destroy the biodiversity of a site, and do so often. But it is also true that much of the Earth's biodiversity has resulted from the presence of humans as peculiar disturbers, for whom fire is a preferred enabling device. What is destroyed today is not raw nature encountering *Homo sapiens* for the first time but landscapes shaped in long association with assorted human practices. The destruction results from the removal of those practices as much as from the removal of the vegetation. (Thus the Swedish national park Dalby Söderskog boasted 208 species in 1925 and only 122 in 1970, having been exempted from the cutting, grazing, burning, and plowing that it had known since the retreat of the ice sheets.)

The issue is not whether humans are present but the character of human presence. Shutting an area off from industrial exploitation does not, by itself, ensure the protection of the species or ecosystem that existed previously. An emphasis on natural processes may do no better unless those processes also include select anthropogenic activities, fire among them. Humans cannot be abstracted from the Earth without effect on the natural system, some biomes becoming enriched, and some impoverished. Even where it can be done for several decades, we have learned painfully that fire exclusion is an error. The next phase is to admit that abolishing all anthropogenic burning is as much an error as the attempt to abolish all fires.

I suggest that the problem is more one of confusion than hypocrisy, and that part of the dilemma is that the cultural precepts, both written and unwritten, that have sustained the enthusiasm for wilderness have changed. Other ecological values have clambered to supremacy, like ecological integrity and particularly biodiversity, which seem to resonate better with the politics of cultural diversity. Preserved lands, that is, exist for many purposes, not all of which synchronize. The assumption that one set of practices will equally serve all these purposes is untrue. I take it as symbolic that Roderick Nash, rather than further revise "Wilderness and the American Mind," (Nash 1982) has written "The Rights of Nature," (Nash 1989) a broad survey of biocentric philosophies. That is where nature preservation is going. And it is where fire management in wilderness and parks must also go.

## WILDERNESS FIRE: THE LEGACY

Despite its ambivalences the legacy of wilderness fire has been immense—and reciprocal. At first such fires granted wilderness management a graphic iconography of what allowing natural processes to range freely meant. Towering smoke columns testified to the power of untrammeled nature, a burnt offering ascending to Nature's Creator. But fire didn't remain only a symbol; it couldn't be finessed in the field as readily as in philosophies. Eventually wildfire boiled off the philosophical froth, and left managers standing in a pall of doubtful practices. In the end fire has compelled a reconception of wilderness.

But if fire forced wilderness management to change, so too has wilderness compelled changes in fire management. Wilderness fire chartered a new era in the administration of American fire. It broke the supremacy of fire suppression among fire practices, and chastened the autonomy of fire protection within public agencies, forcing fire into the service of land management and especially wilderness values; it validated prescribed burning, placing fire use into parity with fire control at least in principle; it shattered the hegemony of the Forest Service as a fire agency, and broke through the boundaries of forestry as a controlling profession over wildland fire; it inspired an efflorescence of research, notably in fire behavior and ecology and particularly in applications; it redefined the meaning of control to include information, and rewrote policy accordingly, allowing the power of prescriptions to take the place of traditional fireline forces; it devised reasons and techniques for dealing with natural fires in wilderness areas; and, based on this cloudburst of change, it inspired a massive exercise in replanning. If you conceive of American fire history in terms of "problem fires," each of which dominates the scene for roughly 20 years, then wilderness fire clearly qualifies. It informed an age.

With the clarity of hindsight, it is obvious that the fire establishment was primed for reform, already by the late 1960's overextended and misshapen. Fire protection was squeezed by the pressure of diminishing returns and the failure of existing methods to suppress an irreducible quantum of large fires. It could not adequately control fuels, and hence wildfires. It could not satisfy ecological objectives, nor could it reconcile its heavy-handed mechanization with wilderness values. It had to change. But it was not obvious in what directions fire protection would change or by what means. The wilderness movement furnished those means and ends.

The era's most spectacular achievement is probably its vindication of prescribed burning. If fire was essential for

wilderness areas, then it could also be good for other, less pristine environments. This intellectual conviction merged with other considerations—like a buildup of fuels in some environments; like an accelerated awareness about the potentials for prescribed fire in the service of biocentric goals, spearheaded by the Tall Timbers Fire Ecology conferences. But fuels had built up implacably in some areas for decades without leading to the almost universal adoption of prescribed fire as a solution. Similarly, the range of applications for prescribed fire might have expanded only slowly, site by site, purpose by purpose, without becoming a generic solution to fire management's problems or claiming status as its defining policy.

Instead prescribed fire became identified with wilderness fire. It was not practical issues like fuels that led to the fervor for prescribed fire; it was conviction about the value of prescribed burning, inspired by a wilderness ideology, that encouraged a search for legitimate uses. It was as if distributing prescribed fire became a surrogate for distributing the saving wilderness. No site was too abused for redemption by prescribed burning, no reason too implausible to justify its application; every dimension of wildland management had, it seemed, a record of fire in its past and cause for fire in its future.

In the flames of prescribed fire techniques fused with ideas. Some practices, such as fuel reduction and habitat maintenance, channeled prescribed burning into areas of traditional concern to foresters and helped connect old concerns with new goals. But others escaped. Once ignited, those fires broke through the institutional and intellectual control lines forestry had laid down. Other agencies and professionals demanded to share in decisions regarding fire practices and policies. Wildland fire no longer remained the unique purview of forestry or the Forest Service. It is probably no accident that wilderness fire, prescribed burning, and the evolution of collegial institutions for fire management, from National Interagency Fire Center to the National Wildfire Coordinating Group, occurred simultaneously.

To counter its accomplishments, however, the era of wilderness fire created an equally impressive array of breakdowns, operational dilemmas, and intellectual paradoxes. Wilderness fire management was an innovation. It had to be used in order to be understood, and understood before it could be used properly. There were, accordingly, plenty of failures in the field—prescribed fires that fizzled out, prescriptions that yielded unexpected outcomes, controlled burns that went wild. For over a decade, from the mid-1970's to the late-1980's, many of the spectacular failures of fire management involved prescribed burns that went bad.

One does not have to be a Hegelian to see that a kind of dialectic is at work here. At first wilderness fire was defined and promoted in terms of the problems it solved; eventually it was shunned because of the problems it created. It began as an alternative to failed practices and a repugnant philosophy. It concluded as itself a hopeless quagmire, its bright flames reduced to a bureaucratic landscape of smoldering guidelines and ashy punditry.

In retrospect it is apparent, moreover, that nature favored the experiment. After the 1978 reforms in Forest Service policy and Park Service guidelines, the American West experienced a cycle of relatively benign fire seasons. Within that climatic nursery prescribed fire, and especially wilderness fire, grew to a kind of maturity. Then drought returned, wildfires raged, and prescribed burning as a privileged practice ended in Yellowstone's 1988 *Götterdämmerung*. Had the reformation begun 6 or 8 years earlier or been delayed an equivalent time it is likely that it would have failed or evolved in dramatically different ways.

## WILDERNESS FIRE: THE BIG BURN

Then came the fires of '88. The Yellowstone fires were more than a biotic spectacle: they were a cultural epiphany like the stock market crash of '29 or the landing of Apollo 11 on the Moon. They were as much an expression of American society as the conflagrations that raged that same year in Borneo, Amazonia, and Thrace were of Indonesian, Brazilian, and Greek society, respectively. The fires stated boldly and confusedly that Americans sought a special relationship with nature but that they were unable to match goals with methods, or institutions with values.

Yet something else transformed failure into debacle, and metamorphosed the Yellowstone fires into probably the most shameful fires of our national history. It was not just that they were strategically mismanaged, which they were, or that officials spent an obscene amount of money, which they did, but that the park acted in bad faith. It did not do what the policy under which it acted required it to do. It promoted a prescribed natural fire program without the bother of prescriptions. It exploited a national commitment to wilderness fire to camouflage its own obsessions. Then it deflected criticism onto the national policy, which was appropriate, and away from the park's execution under that policy, which was flawed by an arrogance that bordered on institutional autism. The blows it dodged fell on others. Because fire ecology includes humanity, events occur within the energy pathways and nutrient cycles of a global economy; information and policies cycle as well as carbon and phosphorus; what occurs in one place can be diffused throughout the country. The ecological effects of the Yellowstone fires fell to parks and forests in Florida, Minnesota, New Mexico, and Oregon. By allowing the deception to stand, the American fire community as a whole must share in the shame.

Those fires ended the era of wilderness fire. It is important to acknowledge that the era was already fading, and would have assumed a new avatar with or without Yellowstone. Even as the conflagrations raged, America's quest for fire sent it hiking out of the backcountry and into exurbia. What American civilization packed into the wilderness, it now packed out. Revealingly, those immense fires posed no new questions to the fire community, nor offered any new answers. The conundrums that had emerged over the purposes of wilderness fire and the suitable means by which to attain them remained.

But as a consequence of the fires, Federal fire policy was reevaluated, and fire plans nationwide had to be resubmitted. Wilderness fire had to rebuild itself, park by park, wilderness by wilderness. And it would have to do so in a context in which industrialization was compelling anthropogenic fire to compete not only with lightning but with fossil-fuel combustion, and in which global environmentalism

was condemning all fires, wild or prescribed, as the flaming matches set to kindle a global apocalypse. Probably wilderness fire will never fully recover. Almost certainly it will never again assume the commanding role it had claimed for nearly two decades.

Wilderness fire management will have to reconstruct itself without the moral enthusiasm and philosophic privilege it possessed when it had led rather than defended its reformation. Revolution had become Establishment. The wave that carried wilderness fire had crashed on shore some time ago, and advocates now stood in the sinking sands of its backwash. What John Dewey had observed about great philosophical questions—that they were never solved in any technical sense but simply "got over" while society moved on to other matters—applied to wilderness fire. Wilderness had become one form of wildland management among many; prescribed burning, one fire practice among others; and wilderness fire, one fire management task among dozens, with no particular claim to priority.

## WILDERNESS FIRE: A REBURN

In the climax to Flannery O'Conner's novel "The Violent Bear It Away," a boy raised according to a grotesque fundamentalism kindles a fire:

> There, rising and spreading in the night, a red-gold tree of fire ascended as if it would consume the darkness in one tremendous burst of flame. The boy's breath went out to meet it. He knew that this was the fire that had encircled Daniel, that had raised Elijah from the earth, that had spoken to Moses and would in the instant speak to him....
>
> When finally he raised himself, the burning bush had disappeared. A line of fire ate languidly at the treeline and here and there a thin crest of flame rose farther back in the woods where a dull red cloud of smoke had gathered.

In a sense that is a description of what the violence of the Yellowstone conflagrations, nurtured on an environmental fundamentalism, had also borne away. What began as a kind of oracle and apocalypse ended as the mundane and the languid. A burning bush became a brush fire. By 1992 the National Park Service had reconstituted fire programs for 16 parks, and the USDA Forest Service for 13 wilderness areas; but the actual acres burned plummeted, no longer ecologically significant. A General Accounting Office report (GAO 1990) lamented the retarded pace of reconstruction. What remained—the unglamorous intellectual and bureaucratic mopup—was to redefine the character of wilderness fire and to relocate it within the larger geography of American fire management.

Fire, wilderness, and humans together form a kind of fire triangle. Clearly fire is indispensable to natural areas. Most American ecosystems in fact suffer from a fire famine. Unburned fuels stockpile in alarming quantities, the combustion equivalent of a toxic dump. But what kind of fire regime is most appropriate is not obvious, nor what kind of Superfund might pay for restoration. Likewise, fire is inextricably bound to humanity, part of our heritage as a species, our perhaps one unique biological niche. The synaptic charge among neurons of the human brain is as vital to the Earth's fire circuitry as the electrical discharge between sky and ground that makes lightning. It can thus be argued that humans had a moral duty to exploit this biological imperative, that along with the power to use fire came the obligation to use it—to use it wisely but to use it. Without fire neither nature nor humanity could be what they are.

So if fire is a point of discord, it is also a means of integration. It remains a **focus**, literally, for any human engagement with our surroundings. I remind you that "focus" in its Latin roots means "hearth," and also altar, home, and family. ("Focus" is thus cognate with the Spanish *fuego* and Portuguese *fogo*.) What we have lost is wilderness fire as an informing principle and a moral crusade. What we have gained is the continued presence of fire in the wilderness as a unique expression of earth, sky, fire, and humanity.

The practical problems of wilderness fire management are solvable. For the most part, except where fanaticism and metaphysical euphoria overwhelm field operations, solutions exist already. They are neither perfect in conception, nor flawless in execution. They fail from time to time, though less often as experience mounts. But then every fire practice fails. Prevention fails. Fuel treatments fail. Prescribed burning fails. Suppression fails. What makes natural fire programs distinctive is that they are based on a calculated ambiguity. They assume that we can have a fire that is both natural and anthropogenic, a fire that is equally and simultaneously wild and regulated. They proclaim that it is possible to control a free-burning lightning fire through the application of knowledge, encoded into prescriptions and forecasts, and that it is possible to deliberately ignite fires which, by virtue of their wilderness surroundings, assume the qualities of wild nature.

The techniques for managing such fires can work, but only if there is some social consensus regarding the philosophy of values behind them. This debate has revolved around two issues, one concerning the source of the fire and the other the nature of control over a fire once it has begun. The first questions whether lightning is the only legitimate origin for the ignition of wilderness fire, or whether anthropogenic sources can also serve. (Can you have an "impure" fire on "virgin" lands?) The second asks whether, if lightning is accepted, under what conditions it can be "managed" and still remain a "wilderness" fire. (Can mortals create a vestal flame?) Or more broadly can humans manage a wilderness from which in principle they are excluded?

These dilemmas disappear, however, if their premises are reexamined. The land was not virgin, and it has been an ecological and moral duty of hominids since the days of *Homo erectus* to actively manage fire. Because anthropogenic fire is a symbiosis between humans and the Earth, not to burn can be as ecologically fatal as promiscuous burning. Removing anthropogenic fire from many environments may be less an act of humility than of vandalism, no different than damming rivers or hunting moas to extinction. The contractions embedded in such concepts as the prescribed natural fire are only paradoxes. They are no different logically than the dense mass of paradoxes around which orbit most of the great advances in modern science and philosophy.

The revolution in 20th-century thought—call it Modernism—has grappled with just such questions of

self-reference and self-inclusion and of the complementarity of observed opposites. Modernist physics, philosophy, and mathematics couldn't resolve those issues; they had to accept them as paradoxes. Is an electron a particle or a wave? Can a mathematical system be both complete and consistent? Can we know precisely the position and velocity of a particle, or does the act of observing interfere in such ways that it limits the information available? Does the set of all sets include itself? The register is long, and it has expanded to other realms—the Antarctic Treaty, for example, which artfully grants and denies sovereignty in the same breath.

Once incorporated as paradoxes—which impose limits on what we know and how we know it—those fields of inquiry expanded enormously. On Gödel's example, systems of thought could be complete or consistent but not both (Kline 1980). They can be consistent but at the cost of ignoring important pieces, or they can be complete but at the price of logical closure. This is exactly the philosophical situation with wilderness fire. We can have a wilderness that is consistent yet missing parts, or one that is complete yet ideologically flawed. We can have a vestal fire that is pure but inconstant, or one that persists but only through human tending. Wilderness fire is Modernism as land manager.

The question has no technical or scientific or even logical solution. The paradox simply is. It may take many forms, but it has no further derivation. Deny the paradox, and you deny the possibility of practical management. Accept it, and despite its irreducible ambiguities, you are liberated to act. Is a prescribed natural fire wild or controlled? (Is an electron a particle or a wave?) Are humans a part of wilderness or not? (If the barber cuts the hair of everyone in the village who does not cut his own hair, who cuts the hair of the barber?) Can anthropogenic fire be a part of wilderness management? (How can you experiment on an electron if, by the act of measurement, you change it?)

If mathematicians can live with Gödel's proof and logicians with Russell's paradox, if physicists can function with the principles of Heisenberg and Bohr, of indeterminacy and complementarity, then the fire community can cope with the theoretical paradoxes of wilderness fire management without lapsing into scholasticism or lethargy. Certainly those intellectual scruples offer no excuse to withhold fire or to dismiss anthropogenic burning. Fire, including anthropogenic fire, belongs in wilderness, not only because sites are small or oddly shaped or have suffered disruptions from European contact but because it was always there. Together lightning and people made the elastic matrix that defined the fire regime.

These intellectual concerns are nonetheless not trivial. There is a passage in Dostoevsky's "The Possessed" in which a fire breaks out on the thatched roofs of a village, the scene of revolutionary unrest. A visiting noble asks what one man, scrambling on a ladder, is doing. "He is putting the fire out, your Excellency." "Not likely," came the reply. "The fire is in the minds of men and not on the roofs of houses."

So too was wilderness fire a fire in the minds of men and women. It would not be addressed solely on the thatched roofs of the Sierra Nevada or the Selways or the Mogollon Rim. It had to speak also to the mind and heart. It had a symbolic role for its nurturing culture as powerful as its ecological role in reserved biotas. The purpose of the vestal flame has never been simply to preserve fire but to preserve a society, to keep alight its national identity and destiny, to instruct its people in who they are and how they should behave. Wilderness fire spoke to just such aspirations, that American civilization had origins more noble than land speculation and stripmining, and a future that transcended shopping malls and the cold war.

Such visions are an inextinguishable part of the complex character of anthropogenic fire, the reconciliation of nature with culture, belief with practice, hope with history. And if the task seems promethean, wilderness fire managers might well echo the words that Aeschylus attributed to the original Prometheus more than two millennia ago. In "Prometheus Bound" he has the tortured Titan proclaim that he "caused mortals to cease foreseeing doom." To this the chorus asks: "What cure did you provide them with against this sickness?" Prometheus answers, "I placed in them blind hopes.... I also gave them fire."

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# Managing Risk in Wilderness Fire Management


## Jerry T. Williams


There is no question that, as an agency, the USDA Forest Service needs to move forward with wilderness fire plan completion. There are 387 designated wilderness areas on National Forest System lands. In 1988, about 50 wilderness fire plans were approved for implementation. In 1992, only 13 plans were operational (at least one revised plan covers three wilderness areas previously handled separately). The decline in plan numbers probably reflects the apprehensions—both external and internal—that developed after the fires of 1988. Certainly, 1988 demonstrated the kinds of risks that can accompany the wilderness fire program.

Following the 1988 fire season, a multi-agency Fire Management Policy Review Team was established by the Secretaries of Agriculture and Interior. It found that the policy of allowing fire to play its natural role in perpetuation of the wilderness resource was sound. However, the team recommended that the means to implement that policy be strengthened. Most of the team's focus centered on risk management and the need to better mitigate potential dangers.

Within the Forest Service, we seem anxious to reduce risks, but we may be going about it in the wrong ways: Are we avoiding risk by simply not developing implementation plans or, perhaps more troubling, by surreptitiously meeting wilderness objectives through application of contain/confine wildfire strategies? My sense is that there remains some uncertainty over the means to meet wilderness objectives. Work toward some "wilderness condition" seems feasible, but inconsistent with a larger wilderness ethic. On the other hand, the risks involved in allowing wild processes to work—to many—seem to carry unacceptably high risks. The fact that we've been slow to reestablish wilderness fire plans may, in part, reflect our inability to come to terms with how best to move the program forward.

The 1988 fire season showed us much about the importance of basing decisions on fire regimes and their associated fire behavior characteristics. Although our policies are necessarily broad, we are learning that implementation of programs must be based on the fire regimes and fire dynamics that represent the area under consideration.

In 1988, the most difficult fires occurred in stand-replacement fire regimes. Where these fire regimes dominate, relative control capabilities are low and risks are high. Major fire runs or long distance spotting can quickly exceed wilderness boundaries, particularly in smaller areas. Although a few western wilderness areas (like the 2.3 million-acre Frank Church River of No Return Wilderness) are very large, many more are relatively small.

Wilderness fire programs can carry high risks, but the risks become inherent in stand-replacement fire regimes where drought conditions are an important—and indeed necessary—predisposing factor to the kind of fire behavior that is natural in terms of ecological process. When burning conditions develop in these types, long-duration fires and high-intensity burning characteristics are common. The opportunities to check fire spread diminish rapidly as fire size increases in stand-replacement fire regimes.

In natural ecosystems, stand-replacement fires occurred most commonly on the wetter, cooler sites. However, the prolonged absence of fire has changed burning characteristics all along the moisture-temperature gradient. Even on warm, dry sites—where multi-storied stand conditions have developed—fire behavior characteristics have changed from low-intensity, stand-maintenance burning to severe, high-intensity stand-replacement burning. Long-term fire control has effectively reduced the natural mosaics that broke up continuous, highly flammable stands and probably once contained fire spread under all but the most extreme conditions.

The objectives of fire management in wilderness are to:

- Permit lightning-caused fires to play, as nearly as possible, their natural ecological role.
- Reduce, to an acceptable level, the risks of wildfire—both wildfires within and those escaping from wilderness.

Unless the Chief of the Forest Service gives approval, the only reason management ignitions can occur in wilderness is when the need to reduce unnaturally high hazard fuels is present. Even then, however, the management ignition option can only go forward when four conditions are met:

- Fuel treatment measures taken outside of wilderness are not sufficient to mitigate the risks within wilderness.
- Lightning-caused fires that might occur represent too great a risk.
- The public is involved in discussions leading to the decision.
- An interdisciplinary team has reached consensus on the management ignition option.

Lightning ignitions are greatly favored in the wilderness management program. Although, in terms of policy,

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management ignitions are allowed if certain criteria are met, they seem to be avoided because they are broadly regarded as manipulative. Although management ignitions may appear to be in conflict with wilderness values, they have an important advantage: they allow for a wider use of fire and enable managers to better mitigate the risk of exceeding boundaries by choosing the time and the place of ignitions. They are not without risk, but on an interim basis, until more natural, potentially less hazardous fuel conditions can be re-established, management ignitions need to be given more consideration. They may be particularly advantageous in stand-replacement fire regimes. Less risky late season management ignitions can emulate fire's natural ecological role when proximity to boundaries or the absence of lightning may otherwise preclude fire's presence.

The alternative of waiting for natural ignitions in the right places at the right time of season appears risk sensitive, but the strategy may actually increase flammability potential over time when there are no upwind or late-season ignitions that are acceptable within planned constraints. Perhaps ironically, overlooking the management ignition option may be constraining the larger need of letting fire play its ecological role in wilderness. We need to re-evaluate our biases against management ignitions in the context of the fire history, wilderness size and shape considerations, risk, and the fire regimes that dominate many of our wilderness areas.

We must not overlook the fact that, regardless of the kind of ignition, the wilderness fire program carries with it potentially high risks. Although there is a growing awareness of fire's role in some ecosystems, there remains a large segment of the population that does not understand the rationale for the wilderness fire program, nor do they seem to be aware of the long-term consequences of excluding fire. While we need to take the case forward for fire in wilderness based on science, with confidence and conviction, we also need to build understanding for the program among our publics.

Although we are focusing on wilderness management, in principle, many of the same challenges, feelings, and apprehensions that surround this program will surround the implementation of ecosystem management. The dilemma is: How do we sustain fire-adapted ecosystems within acceptable limits of risk? Our policy already allows us the latitude to move forward. We need creative new techniques that enable us to implement the policy.

In fire-adapted ecosystems, there are risks in using fire, but there are also serious risks in excluding it. As long as we internalize the risks, steadfastly keeping them as an agency responsibility, the wilderness fire program, and the larger goal of managing for whole ecosystems, will remain vulnerable to public criticism and subsequent agency impasse. We cannot abrogate our responsibilities. We need to mitigate risks to the fullest extent possible, but we need to give thought to partnerships that share those risks that remain.

# National Park Service Fire Policies and Programs

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Following the Yellowstone fires of 1988, the Fire Management Policy Review Team (USDA-USDI, 1989) concluded that the objectives of policies governing prescribed natural fire programs in national parks and wildernesses were fundamentally sound. They noted that these policies allow "...managers to restore and maintain the natural role of fire on land when the land management objective is to perpetuate natural processes and values." But they also recommended that implementation of those policies be refined, strengthened, and reaffirmed. So, the National Park Service made major changes in the way fire policies had previously been implemented.

The Policy Review Team also noted the many positive effects from prescribed natural fires and acknowledged that many felt that, "Overreaction to the events of 1988 should not be used to justify severe curtailment of their use." Has severe curtailment of prescribed natural fires resulted from the post-Yellowstone fire changes in the way we implement fire policy? Are the inter-agency changes in the way we implement fire policy causing us to miss ecologically significant fires? If so, what should we now be doing to modify that result?

In this paper we will review those changes to determine what impacts they have had during the past four years on prescribed fire programs and natural ecosystems in parks and wilderness. It is also important to review the original intent of the prescribed natural fire program, its relationship to the resource management goals of the National Park Service, and to assess whether the current program, as it has evolved since 1988, still meets these goals.

## NATIONAL PARK SERVICE FIRE POLICIES

### Prescribed Natural Fires

**Pre-1988**—The prescribed natural fire policy is, in part, a product of the 1963 Leopold Report (Leopold and others, 1963). The report suggested the National Park Service reconsider its fire suppression policy, and consider the ecological influences of natural fire. By 1968, Sequoia and Kings Canyon National Park in California had established the first prescribed natural fire zone; other parks followed in the next few years, and lightning-caused fires were allowed to burn in portions of these parks.

In support of these programs, between 1968 and 1986, National Park Service fire management policies had evolved to include broad, philosophical support for prescribed natural fire or management-ignited prescribed burning as a surrogate for natural fire (Kilgore 1976; Parsons and others 1986; van Wagtendonk 1991).

These management policies stated that: "The occurrence of natural fire within a given ecosystem is recognized as a potent factor stimulating, retarding, or eliminating components of the ecosystem." And then in a strong statement of support for natural fires, "Most natural fires are lightning-caused and are recognized as natural phenomena which must be permitted to continue to influence the ecosystem if truly natural systems are to be perpetuated."

The 1986 management policy also established that, "Prescribed natural fire is the preferred means to achieve the fire management objectives in natural zones." It said that, "...Prescribed burning may be used as a substitute for prescribed natural fire in natural zones only where the latter cannot meet park objectives...." And finally, it concluded, "In natural zones, the objective for prescribed burning is to simulate, to the fullest extent possible, the influence of natural fires on the ecosystem" (USDI NPS 1986).

**Post-1988**—By 1990, the revised management policies for park fire management programs, on the other hand, appear to have toned down the apparent substantial commitment to allowing natural fires to burn wherever possible, probably in response to recommendations in the Fire Management Review Team's report. Revised policies, however, still include the statement that, "Prescribed natural fires are the preferred means for achieving resource management objectives in natural zones." And there is a continuation of the commitment to use management-ignited prescribed fire with conservative prescriptions to restore an area to a natural range of conditions before allowing use of prescribed natural fires again.

For the first time in 1990, there is specific reference to the willingness of the National Park Service to accept high-intensity crown fires under appropriate circumstances: "Permissible prescribed fire intensities may range from creeping surface fires to stand-replacing crown fires provided that the fire behavior is reasonably predictable and the effects are acceptable as defined by the prescription and management plan." (USDI NPS 1990).

### Management Ignitions

**Pre-1988**—Policies on management-ignited fires in 1986 also tended to be philosophical and broad, noting primarily

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that the use of fire is an acceptable and often advantageous means to achieve management goals. Such policies did note that the power of fire as a tool makes it imperative that all use of prescribed fire be restricted to programs specifically defined in the fire management plan for each park. It was clear that written and approved prescriptions and plans that defined objectives and methods to achieve them were prerequisites to any use of management-ignited fires. It is also significant to note that prescribed burning was an acceptable means to reduce unnatural fuels in wilderness, or to simulate natural fire.

**Post-1988**—In 1990, the wilderness fire management guideline (NPS-18) had become much more specific, more detailed, and more clear. Fire in National Park Service units, it declared, is used "as a natural process and as a tool." In some areas where "fire is an integral component of the ecosystem," it is managed as prescribed natural fire. In other areas "where fire is an essential component of the ecosystem but cannot be allowed to burn as a natural process because of management constraints," management-ignited prescribed fire is used as "a tool"—a surrogate for natural fire—to accomplish resource management objectives.

## NATIONAL PARK SERVICE FIRE MANAGEMENT PROCEDURES AND PROGRAMS: NPS-18

### Procedures for Conducting Prescribed Natural Fires

The 1986 version of the wilderness fire management guideline (NPS-18) contained a simple three-part objective. By contrast, the 1990 revision of the guideline (NPS-18) contains 15 specific "wildland fire management objectives" (USDI NPS, 1990) including these four:

- Protect human life and property within and adjacent to park areas
- Perpetuate, restore, replace, or replicate natural processes to the greatest extent practicable
- Protect natural and cultural resources and intrinsic values from unacceptable impacts attributable to fire and fire management activities
- Manage all forms of wildland fire (wildfire, prescribed natural fire, and prescribed fire) to achieve identified management goals.

In general, the definition of policy, and the requirements and procedures to implement the policy, have become increasingly rigorous. While the revised policy guidelines and procedures insure greater agency compliance with policy and consistency in carrying out procedures, they also have contributed to the decline in acres burned by prescribed natural fire.

The four-page general guidance provided for prescribed natural fires in the 1986 version of NPS-18 grew to more than 20 pages of detailed guidance in 1990 after the Review Team's report was in. This enlarged version of NPS-18 includes nearly a dozen references to the superintendent's daily certification that each prescribed natural fire is in prescription, is expected to stay there for another 24 hours, that all is well with fire management resources and funding, and that the planned and acceptable perimeter will not be exceeded.

Chief among these factors which are thought to have caused a decline in prescribed natural fire acreage, then, are the method of funding prescribed natural fire, monitoring and documentation procedures, and preparedness planning (Botti and Nichols, this proceedings).

As a result of this modification of fire management guidance, major changes were made in fire management plans in places like Yellowstone and somewhat less significant changes in programs at Sequoia-Kings Canyon. Additional prescription parameters were added, the decision process was laid out more specifically, and interagency regional contingency and preparedness plans were completed. While the Sequoia-Kings Canyon program was back on line by 1990, it took until 1992 to get the Yellowstone plan completed and the program back on line. A formerly somewhat freewheeling program in Yellowstone has become a far more conservative program, with more direction for its decisions.

Some of this may be desirable, particularly if you are an adjacent landowner with different objectives from those of the National Park Service. On the other hand, there is substantially decreased likelihood that ecologically significant fires will be allowed to burn over the short term in other National Park Service areas, particularly those in the West, Southwest, and Southeast with shorter fire cycles. This will, of course, simply postpone the inevitable fires over the long term, because as many point out, "Mother Nature bats last!"

Between 1968 and 1988, the numbers of prescribed natural fires allowed to burn in national parks grew from 4 fires burning a total of less than an acre in one park to more than 180 fires in certain years. The fires covered a total of more than 55,000 acres a year in 22 parks in some years. The results of this program are shown in Botti and Nichols (this proceedings).

Following the Interagency Team's 1989 report, there were no prescribed natural fires in 1989. By 1992, the program involved 111 small fires that burned a total of about 2,000 acres nationally in 13 parks. Nearly 60 percent of these fires and 95 percent of the acreage were in the two parks—Sequoia-Kings Canyon and Yosemite—where the program had first begun 25 years earlier. Only 17 of the former 26 parks were back on line with a prescribed natural fire program (Botti and Nichols, this proceedings). Under the new, more stringent regulations, fewer fires were being allowed to burn.

### Management Ignitions

Between 1968 and 1988, the numbers of management-ignited prescribed burns each year in national parks reached a maximum of more than 140 burns covering more than 44,000 acres per year in 21 parks (see tables in Botti and Nichols, this proceedings). Such management-ignited burns have continued to expand after 1988 in the aftermath of the Yellowstone fires. As Botti and Nichols (this proceedings) note, this is primarily because of major increases in the burn program at Big Cypress National Preserve in southern Florida. The rest of the program decreased somewhat from about 12,000 to 9,000 acres burned each year.

Nevertheless, this indicates a fairly constant commitment to human-ignited fire programs as contrasted with major cutbacks in the prescribed natural fire program. Prescribed burning is supported chiefly through hazard fuel reduction funds, in which projects are nominated, ranked, and funded. Funding for these projects has been adequate, with drought a significant reason for reduction in the activity of western programs.

## LESSONS LEARNED

One of the most difficult unresolved fire management policy and program dilemmas is what to do about the natural role of high-intensity, stand-replacing crown fires characteristic of many northern ecosystems where terrain is flat and fuels are continuous (Alexander and Dube 1983; Kilgore 1982; Heinselman 1985; Kilgore 1987).

The Greater Yellowstone and Canyon Creek fires of 1988 offer valuable lessons on how managers must deal with extreme conditions of both fuels and weather conditions—circumstances not predicted by the most experienced of fire behavior experts (Rothermel 1991). With extreme drought and heavy winds, about 45% of Yellowstone National Park burned in 2 months time. What changes in management response should we consider based on the results in Yellowstone and Canyon Creek?

With hindsight, Rothermel (1991) noted that the brief 20-year record of data in the Fire Weather Library was far too limited to represent the range of possible weather, while the 300-year burn patterns in the dendrochronological records of Yellowstone Park (Romme 1982; Romme and Despain 1989) documented "very large fires in the early 1700's and mid-1800's that must have had drought and wind conditions similar to those in 1988."

Some of the lessons learned from the Canyon Creek Fire (USDA Forest Service 1989) were:

- Long-term weather predictions for the fire areas do not always materialize
- The greatest single factors which determine the course of some fires are unusually strong and frequent wind events
- Agencies should better utilize data recording drought history and fire severity indicators to assist in predicting fire weather severity
- The prescribed natural fire (unplanned ignition) program lacks status, priority, and adequate funding when unusual conditions are experienced
- Lack of funds may be the driving force to declare a fire a "wildfire" rather than a prescribed fire—even if prescription criteria do not drive it that way
- When a prescribed fire eventually leaves prescription and needs to be declared a wildfire—following unusual weather events that fall outside the normal parameters on which the plan is based—this should not be regarded as a failure of management, nor should there be a stigma attached to the use of emergency funds to suppress the fire.

One of the main lessons from the 1988 Yellowstone fires seems to be that "extensive, high-intensity fires are an infrequent, but ultimately unavoidable element in whatever fire management option we choose in Yellowstone National Park" because "...there are situations in which fires cannot be controlled by any currently available means" (Despain and Romme, 1989).

The Christensen and others (1989) panel report on the Greater Yellowstone Fires of 1988 indicated that, "To extirpate fire completely from a wildland ecosystem is to remove an essential component of that wilderness." The panel felt that, in effect, the only way to eliminate wildland fire is to eliminate wildlands.

The central issue of the 1988 fire season was that stand-replacing natural crown fire, when mixed with politics, the media, and public opinion, is a volatile issue. The fires provided the most severe test for prescribed natural fire policy, and identified areas for operational improvement. Given the controversy which surrounded the policy, it was amazing that it even survived. The Interagency Team Report was actually a vote of confidence for the policy; it is therefore incumbent upon managers to make the policy work as efficiently as possible to meet land management objectives.

## THE FUTURE OF PRESCRIBED FIRE IN NATIONAL PARKS

The future of prescribed natural fires in the National Park Service depends a great deal on the park manager or superintendent, and to some extent on the vegetation and fuels involved. The Interagency Team's recommendations and their development into current policy and procedures have made it more difficult to allow fire to play its natural role as completely as was once the case. While some of these changes were required to insure safety of human life and property, they will also result in a number of fires being suppressed immediately that might have formerly been allowed to burn.

### Impacts on Long-Cycle Forests Compared to Short-Cycle Forests

**Long-cycle Forests**—Whether or not the requirements developed following 1988 will have significant long-term implications for a park's fire regime is debatable. Studies of fire history in the Yellowstone basin (Romme and Despain, 1989) suggest that fire suppression between 1886 and 1972 may have only postponed the fires of 1988 by a few decades. Without suppression efforts, large fires might have occurred during the dry summers of 1949, 1953, 1960, or 1961 (USDI NPS, 1991).

Romme and Despain (1989) concluded that the 1988 fires represent a nearly natural event and were mainly the result of extremely warm, dry, and windy weather coinciding with an extensive forest cover of highly flammable fuels, mainly lodgepole pine established after extensive fires that burned a large part of Yellowstone around 1700. Thus, as park and wilderness managers, we can run (postpone fires), but not hide (delay them indefinitely). Where fuels and fire weather conditions naturally develop in parks and wildernesses, and where long fire cycles are present, in time there will be the type of fire "Mother Nature" and her natural fire regimes designed the country for. Policy limitations on prescribed natural fire may mean little in such areas.

**Short-cycle Forests**—These same policy limitations, however, may be very significant in areas with a short fire cycle. If prescribed fire of a significant magnitude is prevented from occurring in areas with these fire regimes, fuels accumulate and unnaturally intense, resource-damaging wildfires will occur. Ironically, policies which were developed to address the occurrence of prescribed natural fires in the Yellowstone area may ultimately have no impact on such fire regimes characterized by high-intensity, long rotation fires.

## Fire Management Versus Resource Management

The issue of prescribed natural fire has historically been a complex one because it is grounded in both fire management and resource management. Before 1988, resource considerations drove the program in many parks. After 1988, the pendulum has swung over so that prescribed natural fire is driven by fire management considerations. If prescribed natural fire and wilderness are to survive into the 21st century, the pendulum must swing back to where fire and resource management implications are given more equal weight. This may set up friction between fire managers who see prescribed natural fire as an impediment to wildfire response, and resource managers who see it as vital for the maintenance of the natural character for which a wilderness or park area was established.

## Short-term and Long-term Ecosystem Objectives

We first need to sort out what our short-term and long-term ecosystem management objectives are in national parks (Christensen and others 1989). Then we can determine how we as temporary managers of these magnificent public lands should manage the short-term impacts of:

- Allowing lightning fires to burn
- Using manager-ignited prescribed burns to modify the short-term forest conditions in these areas.

Through research we can reassure ourselves of the effects these fires have on the longer term status of ecosystems.

**The Concept "Natural"**—Applying the concept of "natural" is difficult. It involves individual value judgement (Kilgore 1985). "Natural" has to be defined in terms of the special attributes of each park and wilderness area (Johnson and Agee 1988). For example, we need to set specific fire policy goals that vary somewhat from park to park and wilderness to wilderness, based on variables in fire history, fire behavior, fire effects, and fire responses (Christensen 1991). In the case of Yellowstone and other long-term cycle ecosystems, we as managers must decide how much disturbance is acceptable in a park of that size and shape. Are we willing to allow a naturally ignited fire to become so large you cannot contain it in the park? Are we willing to let it burn a major part of the park in one fire? And if not, and we suppress fires when they are small, we face the issue of whether limiting the size of the fire may have negative impacts on park ecosystems.

**More Sophisticated, Explicit Goals**—Our fire policies and goals need to be more sophisticated than simply restoring fire as a natural process. This is true because fire is part of what Norm Christensen (1991) calls a "dynamic, chaotic, and complex pattern of change" in our park and forest wilderness systems. We must try to gradually understand more of these intricate complexities and to adjust our management goals accordingly. In the meantime, we must provide for fire's role as best we can and strengthen our commitment to research and monitoring as we do so (Christensen 1993).

In places like Sequoia-Kings Canyon, a recent workshop suggested using the general goal of restoring and perpetuating "the fire regime and the vegetation structure...that would have existed had Europeans not come on the scene" (Parsons, 1993). More broadly, there is a growing feeling that we need to be explicit about such goals as "preservation of ecosystem processes, biodiversity, and heterogeneity" (Christensen 1991). We see all these as being desirable as we learn more about our parks and wilderness units. All of these are within the realm of the concept we know as "natural" and need to be incorporated in our prescribed natural fire programs in parks. But we are not doing this when we use "no-risk" management concepts to suppress all ecologically significant fires.

## Monitoring Results and Revisiting Policy

It seems reasonable, as the General Accounting Office (1990) recommends, that we develop an interagency program to monitor and periodically report to the Congress:

- The number of opportunities for prescribed natural fires that occur during a fire season
- The number of fires that are allowed to burn and the number that are immediately declared wildfires, and the factors (such as weather, funding, and firefighter availability) that required the fires to be declared wildfires
- The number of prescribed natural fires that are later declared wildfires (including the reasons for this declaration).

We need to answer these questions, using the data collected from the 1992 and 1993 fire seasons. With these data in hand, and new information from research on fire history in both short- and long-return interval fire areas, we should review the policy and procedures developed from the original Interagency Team Report to ensure that "severe curtailment" of prescribed fire programs does not occur. The level of examination should be on a park level rather than a program level, because the answer may be very different for the Sierran Parks, with their short-term fire regimes as contrasted to Yellowstone and the northern Rocky Mountain wildernesses, with their long-term fire cycles.

The fires of 1988 revealed areas for improvement in the management of prescribed natural fire. However, it is important to note that thousands of acres of prescribed natural fire occurred prior to 1988 with few problems; it may be well to ask ourselves if the administrative constraints which have been added have improved the program in the

short-return interval fire areas relative to the 1986 method of doing business. Clearly, prescribed natural fire acreage in the National Park Service has decreased; the reasons for this decline should be examined and policy and procedures refined as needed.

Because of unnatural fuel accumulation and changes in forest structure in certain areas during the past half century, some management-ignited prescribed burns may be necessary in parks and wildernesses as a prelude to allowing prescribed natural (lightning) fires to burn (Kilgore 1982). Depending upon our attitudes toward intense stand-replacing crown fires, human-ignited prescribed burns may also be needed as a continuing part of park and wilderness fire management.

## Make Prescribed Fire More Nearly Equal

Prescribed natural fires need to be elevated to a level more commensurate with wildfires at all levels within the agencies. Once a prescribed fire manager or tactical team leader is assigned to a prescribed fire, that assignment will be their highest priority. That fire would not have to be suppressed because adequate staffing was unavailable. Obviously, protection of life and property would always have the highest priority.

While this approach may appear to conflict with suppression objectives, it is in fact supportive of them. The reduction of hazardous amounts of wildland fuels with prescribed fire will mitigate wildfire activity. While perpetual subordination of prescribed fire activities to wildfire suppression response appears to make sense, in the long run the lack of a complementary and significant hazard reduction program, particularly in short fire cycle regimes, simply postpones the inevitable high-intensity, crown fire.

There is a need for effective wildland hazard fuel management and for a restoration of the natural role of fire to wilderness areas. The opportunities for these activities may sometimes occur during periods of wildfire activity, perhaps in the local area but more likely in other parts of the country. Sharing of fire management resources will have to occur as a general rule if effective prescribed fire programs are to exist.

If such sharing cannot be worked out with the fire management community, it may be necessary for resource and fuel managers to develop a separate prescribed fire organization capable of conducting holding actions and, if necessary, suppressing most if not all escaped management-ignited prescribed fires and prescribed natural fires. This approach was suggested in the team report's reference to the "concept of highly trained, well-equipped and mobile tactical teams to provide on-the-ground monitoring and management of prescribed natural fires."

## CONCLUSIONS

In our efforts to be cautious and reasonable in the aftermath of the 1988 Greater Yellowstone Fire experience, we need to be careful not to suppress all ecologically significant fires in park and wilderness ecosystems (Kilgore 1991). As fire and resource managers, let's look again at the severe restrictions placed on prescribed natural fires.

A program of prescribed fire—particularly one with high-intensity fire—needs management commitment to make it work. To achieve our objective of restoring fire to its unique natural role in each wilderness and park, our nation's best park and wilderness managers must take reasonable, calculated risks. As government agencies and as a society, we, in turn, must find ways to reward—not penalize—reasonable risk-taking by National Park Service superintendents and Forest Service supervisors.

Fire has always been a component of most park and wilderness ecosystems. As managers and scientists, we must work together to assure that our management decisions for parks and wilderness encourage the largest possible role for natural fires—including high-intensity fires—while still giving reasonable consideration to safety of human life and property.

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# Playing With Fire: Vegetation Management in the Canadian Parks Service

## Stephen Woodley

The Canadian Parks Service has a fire management policy that is best described as evolving. The development history of the fire policy and current practices have been reviewed by other authors (Lopoukhine, 1993; Westhaver, 1992; Day and others, 1988, VanWagner and Methven, 1980). The purpose of this paper is to examine the conceptual evolution of the Canadian Parks Services attitude to fire and speculate on where it is heading.

The agency's attitude toward fire has paralleled the broader evolution of management policy. The Canadian Parks Service has moved through distinct stages in conceptualizing how national parks should be managed. These stages have been described by Eidsvik (1985) as protection, preservation, management and finally adaptive management. I modify Eidsvik's eras and rename the adaptive management phase as ecosystem management. In Figure 1, these conceptual stages are described in relation to the Canadian Parks Service's perception of the ecosystem and the agency's response to fire. I argue that the management of fire presents the same kinds of challenges as other ecosystem management issues.

National parks, viewed through the lens of the 1990's, might be described as a societal response to ecosystem decay. Throughout most of the history of national parks and equivalent protected areas, it was commonly thought that simply placing legal boundaries around areas was sufficient. The result would be healthy, self-regulating ecosystems unaffected by humanity's onslaught. This "preservation" stage was accompanied by the perception that national parks were "natural" and wild or "wilderness". Along with these perceptions was the notion that fire was considered to be enemy of the natural world and it was suppressed where practical. The development of the Warden Service in Canada's national parks was largely to fight wildfires. However, the large size of the parks and slow transportation networks limited the amount of actual fire control.

After 1945, the number of visitors to Canadian National Parks increased dramatically and the Canadian Parks Service entered the "protection" stage. Threats to national parks came from legal and illegal visitors doing such things as poaching, trampling and over-fishing. Parks were still considered natural and wild and the job of park management was seen as protecting the parks from threats such as poaching and trampling. Fire was still seen as an evil and fire suppression became much more effective. New equipment was developed, hundreds of fire roads were constructed, and networks of fire towers were erected. During this period it is likely that fire control began to alter the historical fire regime. In this era the management goal continued to be a natural wilderness.

The next phase, which began in the 1970's, has been termed the "management" phase. As in other jurisdictions, there was the growing realization that parks were not always self-regulating, natural ecosystems. Instead of being natural, park ecosystems were increasingly seen as "impaired" and active management was deemed necessary to correct the impaired condition. Attitudes toward fire began to change as fire was increasingly viewed as an important dynamic element in the ecosystem. It was clearly demonstrated that some ecosystems were fire dependent. The Canadian Parks Service responded to the changing attitudes with a 1979 policy permitting active management or manipulation of the ecosystem, under certain well-defined conditions. This was the beginning of the "fire management era." With a new directive produced in 1986 and a comprehensive fire policy review called "Keepers of the Flame," the Canadian Parks Service embarked on a new relationship with fire. For the first time, fire was officially recognized to be an important element in the ecosystem and it was to be restored to its "natural role" by active management. Unregulated wildfire was considered impossible in most parks because of the values at risk. These values included public safety, protection of property and protection of rare species or habitat. Thus, the Canadian Parks Service began to use prescribed fire with an aim to restore the "natural" fire regime. In most parks unregulated natural wildfire continued to be eliminated.

While there are many examples of early use of prescribed fire in grasslands, the Canadian Parks Service quickly began to formally use prescribed fire in the mid-1980's. The greatest activity was in Western Region and notably at Banff, under the direction of Cliff White and Ian Pengally. Presently, prescribed burns are conducted in three of five regions in Canada. As a basis for the prescribed burn program, parks are required to prepare fire management plans and vegetation management plans. These plans are based on an historical assessment of the role of fire in the park and a detailed set of vegetation management objectives.

With some experience in this management era, there have been lessons learned, and many unresolved debates. Against this background, management philosophy continued to develop and we entered the era of "ecosystem management." Because the organization is now in the midst of developing this approach to management, it is fair to call this approach

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| Era (Management goal) | Role of the Canadian Parks Service | Role of Fire |
|---|---|---|
| Protection (natural) | - boundary designation | - excluded where possible |
| Preservation (natural) | - anti-poaching<br>- fishing regulations | - effective exclusion |
| Management (impaired) | - intervention within boundaries | - effective exclusion with limited prescribed fire |
| Ecosystem Management (ecological integrity) | - greater ecosystem approach<br>- ecosystem goals<br>- active intervention<br>- created futures | - fire as ecological process<br>- interagency management<br>- prescribed fire as normal activity<br>- differential response zones |

**Figure 1**—The evolution of park management concepts through four management eras in the Canadian Parks Service and its relation to fire management.

evolving. All the answers and directions regarding this approach are not clear. The remainder of this paper discusses the ecosystem management approach and its impact on fire management.

## ECOSYSTEM MANAGEMENT

The revisions to the National Parks Act in 1988 introduced the term ecological integrity. The term has been elaborated upon in several reviews and publications (see Woodley and others, 1993). This term provides a new model for an endpoint for ecosystem management. As a concept, it supersedes the notion of "natural" as a management endpoint, which has several important ramifications. During the early years of park establishment, Canadian National Parks were often islands of civilization in a sea of wilderness. Park boundaries were only lines on a map and indistinguishable on the landscape. Today the impacts of forestry, agriculture, tourism and urbanization have effectively isolated most parks as islands in a sea of human development. Large-scale ecological insults such as acidic precipitation and climate change have no consideration for park boundaries. Also, large-scale tourism facilities and road networks have been developed within parks. It has become increasingly obvious that instead of being natural, self-regulating ecosystems, parks and protected areas are remnant islands assaulted by a variety of human-caused stresses. The use of ecological integrity recognizes the need to manage parks for a particular ecosystem state that is "healthy." I argue that the use of ecological integrity as a management endpoint is a significant advance from the notion of natural. It forces the use of ecosystem science in combination with societal wishes to define ecosystem goals. Moreover, ecological integrity recognizes that ecosystems are self-organizing entities that are dynamic. There is no one particular state or era in time that is necessarily correct or natural. In its management, the Canadian Parks Service does not attempt to recreate a particular era. In some cases, fire may be used to maintain a successional stage, such as a grassland valley bottom. However, the stage is maintained for defined ecological objectives, such as providing winter forage.

## FIRE AND ECOLOGICAL INTEGRITY

As the Canadian Parks Service moves into the ecosystem management era, there have been a number of problems, disagreements and difficulties. The first is the problem of scale. In the management era, all considerations were within park boundaries. First-generation fire management plans, fuel maps and other planning aids all stopped at the park boundary, despite the obvious ecological and even operational irrelevance of the line. However, with the need to manage on a broader, more relevant scale, the question became how big. Many wanted to simply draw new boundaries at a more ecologically relevant scale. Others argued that boundaries were a problem in themselves and fire management should be considered in broader zones of influence. Perhaps neither perspective is correct for all situations. What is important is that fire and vegetation management in a park be integrated into the surrounding region.

A central debate in the role of fires in parks is over the need to duplicate natural or historical fire regimes. There is no disagreement that fire should play some role in the majority of national parks. However, the exact role of fire becomes mired in the question of the historical role of fire. There are some who argue that fire frequencies have not been altered by human fire suppression (for example in the Canadian Rockies, Bessie and Johnson, this proceedings). This line of argument assumes that fire is a process driven by climate and that it is so powerful that fire frequencies are unaltered, despite multi-million dollar suppression efforts. The argument further states that a few very large, intense fires make up the vast majority of acreage burned. Therefore, prescribed burns are irrelevant and not in keeping with historical fire regimes. There are other researchers who argue that human fire suppression and fire protection has definitely altered the fire regime and that prescribed

fire is essential to create a negative exponential distribution of vegetation patches.

The above dichotomy of viewpoints can paralyze an agency trying develop a fire management program. Using the paradigm of ecological integrity, I argue that neither perspective is correct. Below, I will discuss shortcomings with each perspective and then speculate how an ecological integrity approach might come to a different conclusion for management.

Taking the first perspective, let's assume that human fire suppression has indeed not affected fire frequencies in this century. Here is a classic case where scientific revelation (assuming it to be true) cannot assist management policy. If the historical or natural role of fire is for infrequent, large fires to burn huge areas, how can this guide management in most national parks? Clearly it is unacceptable for large-scale, high-intensity fires to occur in many national parks. In many cases the area burned by historical, large-scale fires would exceed the total area of the national park. Such a large-scale fire would reduce the entire park to an early successional stage, with consequent loss of habitat for species found only in older age class habitats. It would also endanger lives and property in and around the park. Such a situation might be acceptable in a far northern park where the park in embedded in a landscape that is relatively unimpacted by humans. It is clearly not acceptable where a park is embedded in a landscape of intensive agriculture, forestry and urbanization.

An alternative viewpoint is that the park should be composed of a negative exponential distribution of age classes of fire prone vegetation. This idea is a derivation of the larger idea that an entire region should be managed as a negative exponential distribution of age class (Van Wagner, 1978). To maintain this distribution on a park basis, a certain percentage of the park would be burned by prescribed fire each year. For example, if the park was to duplicate a fire cycle of 100 years, then 1% of the park's fire-prone vegetation would be burned each year. This is a simplistic model that has several problems if applied only at the park scale. Most importantly, this model neglects the fact that the park is part of a larger ecosystem. The role of parks is to protect healthy ecosystems with genetic, species and community diversity (biodiversity). The negative exponential model, depending on the size and configuration of the park, offers no guarantee that biodiversity will be protected. For example, perhaps the park is too small to protect a given species or community if only 1% is allocated to it at any given time.

The ecological integrity approach to park management seeks to protect ecosystem structure and functions that are characteristic of the region, unimpaired by human-caused stresses and are likely to persist (Woodley, 1993). However the desired ecosystem structure and function must be defined in realistic terms. The most realistic way to do this is in terms of biodiversity. Fire management is an exercise in patch dynamics, where a given burn creates a patch on the landscape. The important question for managers is what configuration and size of patches on the landscape are likely to protect native biodiversity. If a fire management program is not based on that question, I maintain it is useless.

There might be many practical and theoretical answers to the question of what configuration and size of patches on the landscape is likely to protect native biodiversity. We know that ecosystems are adaptive and self-organizing. It is likely that such systems can tolerate a wide range of fire-return intervals. If we know that a given ecosystem had a fire frequency of 200 years in the 17th century and a fire frequency of 300 years in the 19th century, is the difference of critical importance? Perhaps searching for the holy grail of the exact natural fire frequency is a misplaced quest. Ecosystems can tolerate fire frequencies within a wide latitude and the specific number is not that important. What is important is that fire remains a functional process on the landscape and that the process maintains viable levels of native biodiversity.

As an exercise in patch dynamics, an ecological integrity approach to fire management would integrate fire with other patch-creating processes. An example would be a park surrounded by forestry activity. Done correctly, forestry can create patches of younger-age class habitat adjacent to a park. The park should consider its ecological role in the greater ecosystem in which it is embedded. If older-age class vegetation is being underrepresented in lands adjacent to some parks, then the vegetation management objectives of the park should be to protect a higher percentage of older-age vegetation. This is not to suggest that parks should constantly respond to external land use. Agencies must work together at the regional level to plan vegetation management objectives that ensure biodiversity at a regional level. Only then can most parks develop meaningful fire management plans.

## TOWARD THE FUTURE

Given the above discussion, I can speculate on future directions for fire and vegetation management in the Canadian Parks Service. First, there is a wide recognition that parks must be managed in cooperation with neighboring land management agencies. This process is well underway with many excellent examples in Canada. Data bases, vegetation maps, fuel maps and other planning tools are being prepared on the basis of regional ecosystems, instead of park boundaries. There is also an increase in interagency cooperation in fire protection.

Increasingly, it is recognized that there is no correct formula for fire management. It is not a simple matter of conducting a fire history study and then preparing a fire management plan to duplicate some historical fire frequency. Parks must seek individual solutions to fire management, depending on their own unique situations. In some cases it will be possible to have entire parks, or large zones in parks, where fire frequencies are unaltered by humans (discounting global warming). In these areas, lightning-caused fires can burn without any intervention. They will simply be monitored. This is the case in Nahanni National Park, situated in the northern boreal forest with little development on its boundaries. Some parks will have a mix of observation zones, full suppression zones and evaluation zones. This kind of scenario is being developed in Wood Buffalo National Park. Other parks, especially in the more developed regions of the country, will have to use just prescribed fire.

With the use of prescribed fire, it is essential that detailed vegetation management objectives are in place. The

objectives should view fire occurrence in terms of the patch dynamics on the landscape. To date, the Canadian Parks Service has only a few completed vegetation management plans for its national parks. Several others are under preparation and valuable lessons are being learned.

## CONCLUSIONS

There is wide agreement that fire is an essential process in most Canadian national parks. However, there is still debate about how fire should be controlled or allowed within the parks. I conclude that trying to base the role of fire on historical frequencies is a fruitless exercise. Whether resource managers like it or not, there must be an element of designing our own futures in national parks. The vast majority of today's national parks are too small to be considered natural self-regulating ecosystems, where fire can occur unregulated. To maintain fire as an ecological process, it must be planned and managed on a regional basis along with other patch-forming processes. Ecological integrity offers a management endpoint that avoids the ethereal concept of "natural" and is more firmly rooted in ecosystem science. Vegetation management plans must be grounded in concern for the maintenance of biodiversity.

There is no correct formula for the role of fire in national parks. Individual parks must choose a combination of unregulated wildfire in observation zones, evaluation zones where response to fire is judged on a case-by-case basis and the use of prescribed fire. In all cases, fire management is a tool to contribute to vegetation management. Canadian National Parks resource managers are wrestling with all these concepts as the role of fire in vegetation management unfolds and we attempt to manage on an ecosystem basis. Undoubtedly the road ahead will be difficult and we will have to experiment and adapt.

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# Meeting Wilderness Goals: A Wilderness Specialist's Perspective

**Steve Morton**

**Abstract**—Discusses the concept of setting objectives for prescribed fire in wilderness. The current Forest Service policies are visited as well as the concept of what is "naturalness" and the difficulties in establishing objectives for measuring it. The difference between the wilderness ecosystem and the wilderness resource is discussed as an important distinction for people to make. An appeal is made to allow "natural fire" to tell us what "natural" is, while recognizing that in some units of the National Wilderness Preservation System management-ignited fire may be the only way to return fire to the ecosystem today.

The title assigned to this talk by the program committee, "Meeting Wilderness Goals—the Perspective of a Wilderness Specialist," has given me a number of anxious moments. First, because I tend to think that most of us already know the essential goals of wilderness; second, that any remarks about wilderness in my view demand a degree of eloquence that I have yet to achieve, and third, that wilderness knowledge does not reside in one line of specialization occupied by the few fortunate people whose title is that of Wilderness Specialist.

Many people inside and outside the agencies and institutes of learning are represented here who I consider wilderness specialists. Certainly the fire community is staffed by some of the finest, and so is the line officer cadre, and the academicians, ecologists, biologists, retirees, and interest groups. Some of them and you are my heroes, and my hat is off to you for your willingness to take a stand during past incidents, and even more so for what you will do in the future.

The brief instructions to me for this presentation center around such questions as: (1) Is there a wilderness objective?; (2) Discuss philosophy behind attempts to define naturalness; (3) Can it be done?; (4) Should it be done?; (5) What makes it difficult?; (6) What are some specific ways to describe objectives?; and (7) Give specific examples of ways related to meeting naturalness with fire.

I do appreciate them giving me the easy questions—I don't know what I would have done with the hard ones. All are good questions, and questions that to me go right to the heart of perhaps a central question: "How do you know when you have succeeded with a wilderness fire program?"

Quite frankly, I don't know if I can do this subject matter justice in 20 minutes, but perhaps by the time you have listened to all the specialists during this forum, our heads and hearts will come together with the mix of passion and pragmatism that wilderness deserves as we get on with gearing up for wilderness stewardship for the 21st Century.

## THE WILDERNESS RESOURCE

The Japanese poet Basho, who lived from 1643 to 1694, once said, "To learn about the pine, go to the pine. To learn about bamboo, go to the bamboo." And so it is that I say "to learn about wilderness, go to the wilderness." The story of wilderness fire is written there—almost everywhere. It is perhaps the most striking, observable record of natural history, next to the geology and landforms themselves. Virtually every member of the plant and animal community is in some way dependent on fire for their existence.

As one goes to the wilderness to understand wilderness, one must go to the Wilderness Act to understand the wilderness resource. These two words are often used, but in my experience, not commonly understood.

We talk about the wilderness resource because the Wilderness Act states "...it is hereby declared to be the policy of the Congress to secure for the American people of present and future generations the benefits of an enduring resource of wilderness."

As a wilderness specialist I have spent a lot of time thinking about what the wilderness resource is. I imagine from time to time some of you wonder what drives a "wilderness person" to think and act the way they do. So in the next few minutes I want to share the foundation by which I assess **every** proposed action in wilderness. If we accept the fact that there is a wildlife resource, a water resource, a cultural resource, a vegetative resource, an air resource, and so on, then there is by law a unique and distinct wilderness resource.

Now, it is quite common to hear people describe the wilderness resource as the sum total of all the separate resources and processes contained within wilderness areas. What they are describing is the wilderness ecosystem, not the wilderness resource. Figure 1 is a diagram of the wilderness ecosystem.

Let me say that the same components of ecosystems exist both outside and inside legal wilderness. Let me now give you my view of the wilderness resource, with all its constituent parts taken from the Wilderness Act (fig. 2).

These words and short phrases give us an entirely different set of parameters to define and determine the nature of this resource than are used to qualify and quantify the other unique resources. Words such as timelessness, structurelessness, motorlessness, resourcefulness, and naturalness are quite different from diameter, frequency,

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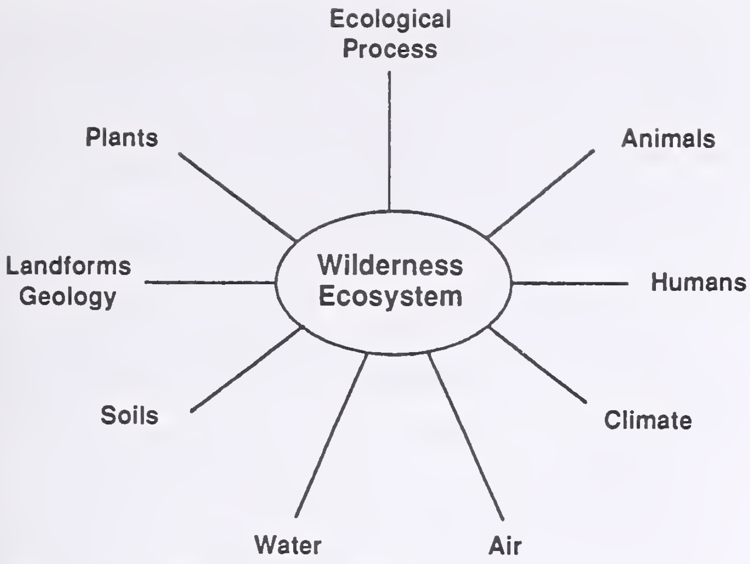


**Figure 1**—The wilderness ecosystem.

abundance, turbidity, pH, population structure, and so on, which are the parameters of wilderness ecosystem components. And before someone takes me to task, I hasten to add that the asterisked elements indicate some exceptions that time does not permit me to discuss today, but are frequently the cause of significant debate.

It is to the degree that these descriptive statements or components of the wilderness resource are compromised that the wilderness resource itself is diminished. And if they are violated enough, we simply destroy the wilderness resource and allow these places that are legislatively mandated to preserve it to become semiprimitive recreation areas. As stewards of this resource, currently one-sixth of the National Forest System and 2 percent of what remains of native America, we must allow wilderness to be unoccupied, unmodified, untrammeled, and affected primarily by the forces of nature. I don't mean affected primarily by the breeze, the mist, the slowly decaying log, the freeze-thaw of water, the unfolding of a flower, or the creeping underburn. The law says the FORCES of NATURE— it must be allowed to grow, snow, flow, blow, and glow.

As Aldo Leopold said, "The foundation of intelligent tinkering is to save all the pieces." And I would add to that—the processes. And so let me pose two questions and answer them as I have concluded for myself. Can the wilderness resource be damaged by natural fire? The answer is no. Can any other individual resource within the wilderness ecosystem be damaged by natural fire? The

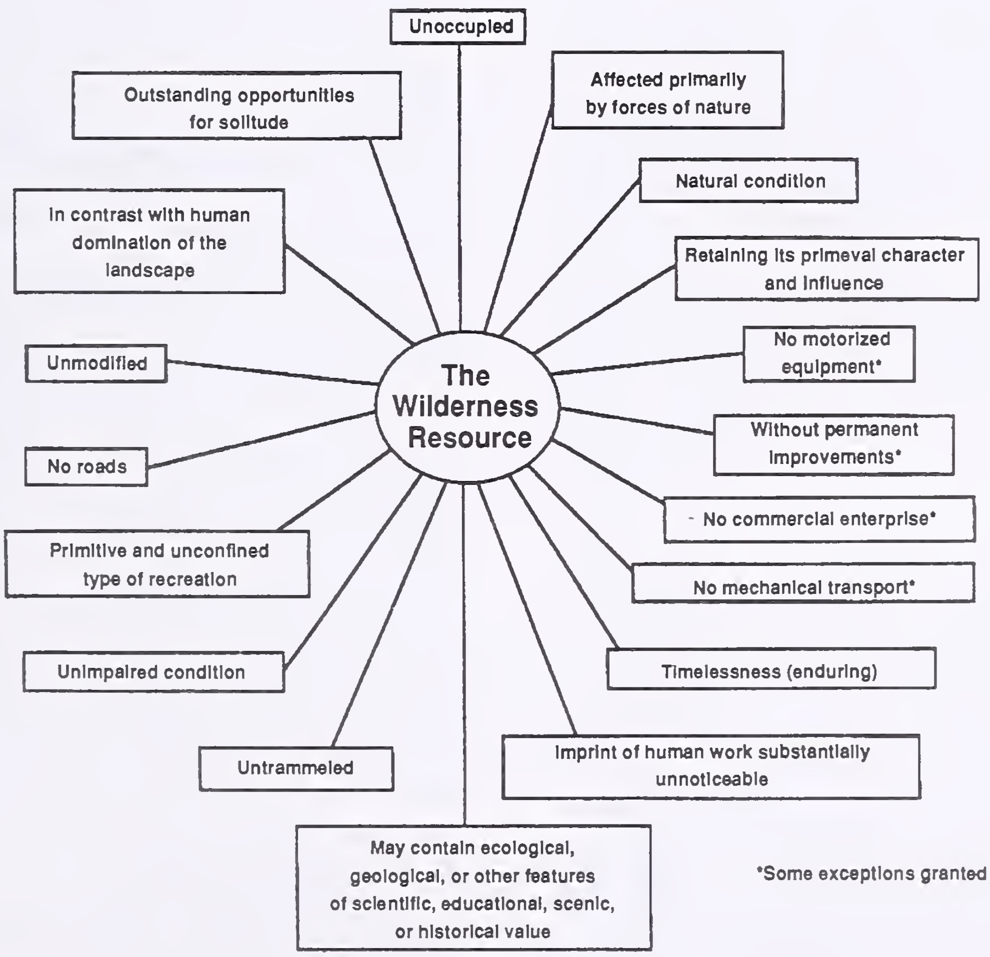


**Figure 2**—Diagram of the wilderness resource, from the Wilderness Act of 1964.

answer is maybe, in the short run. Suppression of any natural ignition always diminishes the wilderness resource, and is done for nonwilderness purposes.

## WILDERNESS OBJECTIVES

Let me hasten to the questions concerning preparing wilderness objectives for the return of fire. There is already current Forest Service policy that speaks to these questions in the Wilderness section of the Forest Service Manual. FSM 2324. Management of Fire. 2324.21. Objectives states: "The objectives of fire management in wilderness are to: 1. Permit naturally occurring ignitions to play, as nearly as possible, their natural ecological role within Wilderness" and 2. "Reduce, to an acceptable level, the risks and consequences of wildfires within Wilderness, and of wildfires that spread from Wilderness."

What is the wilderness consequence of wildfires within wilderness? It is suppression—suppression of objective number one, suppression of fire's natural ecological role, and an eventual subjugation of the very essence of wilderness.

There is existing policy granting permission to utilize management-ignited prescribed fire in wilderness providing it meets all the four criteria in Forest Service Manual 2324.22. Policy. "4a. The use of prescribed fire, or other fuel treatment measures outside of Wilderness is not sufficient to achieve fire management objectives within Wilderness; 4b. An interdisciplinary team of resource specialists has evaluated and recommended the proposed use of prescribed fire; 4c. The interested public has been involved appropriately in the decision; and 4d. Lightning-caused fires cannot be allowed to burn because they will pose serious threats to life and/or property within Wilderness or to life, property, or natural resources outside of Wilderness."

As a point of interest, it is also policy in FSM 2324.22.5: "Do not use prescribed fire in Wilderness to benefit wildlife, maintain vegetative types, improve forage production, or enhance other resource values." And in FSM 2324.22.6: "Where prescribed natural fire can achieve Wilderness fire management objectives, use it rather than management ignited fires."

In the Forest Service Handbook, which provides working guidelines for implementing the policies set forth in the Forest Service Manual (Chapter 70 of FSH 2309.19, Wilderness Management Handbook) we see two important statements: "71 - Fire Management Activities: Conceptually, the first objective of Wilderness fire management is a Wilderness resource management objective, and the second is a resource protection objective." "The 'natural ecological role' of lightning fires (or other natural occurring ignition) in Wilderness is purposefully undefined. This role may not be the same in the future as it was in the past. Therefore, the objective is to let naturally caused fires define the role as ecosystems and climates evolve in the future. The objective purposefully does not attempt to replicate past fire frequencies or fire effects." Notice that the word "wilderness" precedes the word "resource" in the first objective; it does not in the second. So even when the second objective is called on, it is not to protect the wilderness resource.

Time doesn't permit me to go into the effects of fire exclusion on the natural systems, but you know what many of them are, and all the specialists from Autecologists to Zoologists could compile a scenario that is staggering. Without fire the ecosystem is cancerous; without fire the wilderness resource does not exist.

As I wind this down, there is a clear stepdown process that carries the flow of philosophy to implementation. To me, it proceeds this way:

- The goals of the Wilderness Act = law, philosophy.
- Agency policy and guidance = directives and objectives.
- Forest plans, park plans, refuge plans = desired future condition.
- Wilderness implementation schedules = schedules fire plan preparation and cost.
- Wilderness Fire Plan = specific direction for each wilderness and local issues.
- Fire Management Action Plan = annual implementation plan.
- Individual Prescribed (natural or management-ignited) Burn Plan = each incident.

There is room in this process for every component of the National Wilderness Preservation System—over 545 units currently and quite a few more yet to come—to have a Wilderness Fire Plan. They will take many forms, depending on the hand that Congress has dealt and is yet to deal all of us. There is a big job to do, but we must accept the challenges in front of us if we accept the concept of wilderness.

## QUESTIONS ANSWERED

Here are my own answers to the questions posed by the program committee:

1. Is there a wilderness objective? Yes, while more of a goal than an objective, it is contained in the word **wildness**. It is the same goal for fire as it is for every wilderness program, for it is the very essence of wilderness.

2. Discuss the philosophy behind attempts to define naturalness. As interesting as this exercise might be, it is better in my view to allow the natural forces and processes to tell us what it is. We can do fire history, soil analysis, inventory the community and see what appears to be missing, do pollen identification, compare the earliest photographs known to exist, and see that today's ecological community may be different. But we cannot say with great assurance that it was always so. Let the fires return or return them ourselves, and let us not engage in endless attempts at defining naturalness.

3. Can it be done? I don't know, but I think a bundle of money will be spent trying.

4. Should it be done? I think not if it tends to promote endless delays and human engineering of the wilderness resource.

5. What makes it difficult? We weren't there, don't live long enough, and we think in such short time frames.

6. What are some specific ways to describe objectives? If you would accept broad ones in the simplicity of the Wilderness Act:

- Perpetuate the "forces of nature."
- Retain the "primeval character and influence."
- "Preserve the Wilderness character" (wildness).

Or, more specific objectives could be:

- Provide for representation and replication of all ecosystem types.
- Provide for conservation and genetic diversity of species.
- Preserve the spectrum of species.
- Maintain viable populations.
- Provide for conservation of unique habitats and environments.
- Allow the continued flow and exchange of energy.
- Maintain ecological processes, production, decomposition, nutrient cycling.
- Restore health to the ecosystem by creating barriers to pathogens.
- Restore life and beauty to the wilderness.

7. Give specific examples of ways related to meeting naturalness with fire. Simply go to the wilderness and look.

The wilderness resource is now in the hands of all of us. It is capable of having all these qualities:

| | |
|---|---|
| Wild | Rejuvenating |
| Irrepressible | Natural |
| Legendary | Enduring |
| Distinct | Spiritual |
| Enriching | Secluded |

I trust while there is still time we will act with the courage and wisdom as specialists, scientists, and managers to let it **be wilderness.**

# Prescribed Fires in Wilderness: How Successful?

## Robert W. Mutch

**Abstract**—Since 1972, prescribed natural fire plans have been developed and implemented for several of the larger wildernesses in the country like the Frank Church-River of No Return, Teton, Selway-Bitterroot, Bob Marshall, Scapegoat, Absaroka-Beartooth, Gila, and Boundary Waters Canoe Area. The large size of these wildernesses successfully accommodates long duration prescribed natural fires under most conditions. But over 70 percent of the wildernesses in many parts of the west are less than 100,000 acres in size, areas too small to successfully contain long duration, free-burning fires. The management option in these smaller wildernesses, most of them fire-adapted, has been one of fire exclusion through suppression actions. The development of plans for manager-ignited prescribed fires in the smaller wildernesses is one way to ensure that this significant disturbance process once again contributes to the wildness of fire-dependent ecosystems in wilderness.

Since passage of the Wilderness Act in 1964, it has been recognized that fire should be restored to wilderness ecosystems—ecosystems which by law are to be managed to perpetuate areas that are "affected primarily by the forces of nature." Such restoration provides scientific, educational, and esthetic opportunities regarding the role of fire in wilderness ecosystems and allows procedures more in harmony with nature (Habeck and Mutch 1975). As Loucks (1970) observed, disturbances such as fire tend to recycle the system and maintain diversity. He concluded that any modifications of the system that preclude disturbances and recycling would be detrimental to the system.

Since the 1970-1972 Forest Service pilot project on fire management planning and implementation in the Selway-Bitterroot Wilderness, several Forest Service Regions have developed fire management plans for larger wildernesses. Additional plans were developed and approved for such wildernesses as the Gila, Teton, Bob Marshall, Scapegoat, Great Bear, Absaroka-Beartooth, Boundary Waters, Frank Church-River of No Return, and Cabinet Mountains. More recently some plans have been approved for smaller wildernesses in the East. For example, a manager-ignited prescribed fire plan for the 13,600-acre Big Gum Swamp Wilderness in Florida has been implemented. Regardless of the method of restoring fire to wilderness, whether by manager ignitions or natural ignitions, perpetuation of natural ecosystems is the management objective. Ideally, a wilderness fire should be a random event that produces dynamic ecosystem change: killing some trees but leaving others, removing undergrowth in places but also leaving unburned areas, exposing mineral soil, producing open-grown forests or dense stands of lodgepole pine, converting dead organic material to ash, recycling nutrients, restricting some plants and animals and favoring others. Not only are fire-dependent communities well-adapted to such change, but the diversity of plants and animals following fire also contributes to ecosystem stability (Habeck and Mutch 1975).

We need to consider such issues as wilderness size and shape, air quality, endangered species, and unnatural fuel accumulations as important factors in determining the appropriate mix of fire management actions to meet wilderness objectives. We will explore some of these wilderness fire management elements as we discuss the role for manager-ignited prescribed fires in wilderness.

## FIRE HISTORY, FIRE REGIMES, AND FIRE EFFECTS: A STARTING POINT

Understanding fire ecology principles is absolutely essential in developing appropriate fire management strategies for fire-dependent ecosystems in wilderness. Knowledge of the continental pattern of fire regimes will equip us to plan wilderness fire management programs that take into account fire history, fire regime elements, and fire effects. An ecosystem can be called fire-dependent if periodic changes in the system due to fire are essential to functioning of the natural system. In such systems fire is a significant environmental factor that initiates and terminates key vegetational successions; regulates the age structure and species composition of vegetation; produces the vegetation mosaic on the landscape; affects insects and plant diseases; influences nutrient cycles and energy flows; regulates the productivity, diversity, and stability of ecosystems; and determines habitats for wildlife. Such an important ecosystem process as periodic fire needs to be understood, and understood well, by wilderness managers and fire managers if we are to be successful in fulfilling wilderness management objectives at the landscape level for all wildernesses in the National Wilderness Preservation System.

A natural fire regime is the total pattern of fires in vegetation, over time, characteristic of a region or ecosystem, including variations in fire intensity and behavior, fire size, recurrence (or return) intervals, and ecological effects.

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The important elements of a fire regime include:

- Fire type and intensity (for instance, low-intensity surface fire or high-intensity crown fire).
- Fire size or area (this factor determines the scale of the vegetation mosaic—that is, will typical age-class patches be large or small?). Much variation in fire size is usual, but the typical size of ecologically significant fires is a key difference between certain fire regimes.
- Fire frequency or length of "return intervals" in years (as determined for a given point on the ground, such as a tree, or for a stand).
- Frequency for the whole ecosystem—called the natural fire rotation or fire cycle. These terms define in years the average time required for a natural fire regime to burn over an area equivalent to the total area of an ecosystem. In the real world, some areas are skipped by fire for long periods, while others burn two or more times in a rotation. The rotation or fire cycle is still a useful concept for comparing the role of fire in different ecosystems.

This listing of fire regimes is not intended to be complete, and combinations of these regimes often occur within a single ecosystem. Regimes also vary with soil-site, geologic, and topographic factors over short distances in some ecosystems. As with any classification system, you will be able to identify exceptions to the fire regime classes. Nevertheless, the definition of several classes will help in developing a framework of fire regimes for wilderness fire management.

The following classification of fire regimes (Kilgore and Heinselman 1990) is intended to apply to forest fires of natural origin in North America in presettlement times:

0 = No natural fire, or very little. Examples: coastal Alaska, wetter eastern deciduous forests, and most subalpine forests of New England mountains.

1 = Infrequent light surface fires (more than 25-year return intervals). Most fires small in size. Examples: some high-elevation, subalpine forests of the Sierras, Cascades, and Rockies (especially where there is much exposed rock and fuel accumulations are low); open-grown pinyon-juniper woodlands in the Southwest.

2 = Frequent light surface fires (1- to 25-year return intervals), often combined with sporadic small-scale long or very long return interval crown fires. Typical fires are a few hundred to a few thousand acres. Examples: montane zone of the Intermountain and Rocky Mountain regions, including forests of ponderosa pine and mixtures of ponderosa pine and Douglas-fir.

3 = Infrequent severe (often high-intensity) surface fires (more than 25-year return intervals), usually in combination with long return interval (100 to 300 years) sporadic crown fire or higher intensity surface fires. Typical fire sizes are 1,000 to 10,000 acres. Examples: some lower and middle elevation lodgepole pine, Engelmann spruce, and aspen forests of the Rockies in Idaho, Utah, Wyoming, and Colorado.

4 = Short to medium length return interval crown fires and severe surface fires in combination (50- to 100-year return intervals). These are often stand-replacement fires. Fire sizes generally 5000 to 100,000 acres. Examples: boreal forests in Alaska and Canada, lower elevation subalpine zones of the Rocky Mountains and Intermountain ranges. Common types include lodgepole pine, lodgepole pine-spruce-fir, Engelmann spruce-subalpine fir, and quaking aspen.

5 = Long return interval crown fires and severe surface fires in combination (100- to 300-year return intervals). Usually stand-replacement fires. Examples: west slope Douglas-fir, western hemlock, and western red cedar.

6 = Very long return interval crown fires and severe surface fires in combination (over 300-year return intervals). Examples: most high-elevation subalpine forests of the Rocky Mountains and Intermountain ranges. Includes Engelmann spruce-subalpine fir forests, limber pine, and whitebark pine.

## SCALE: WHEN IS SMALL TOO SMALL FOR PRESCRIBED NATURAL FIRE?

Although a random lightning ignition on a wilderness mountainside that burns in an unplanned manner for days or even weeks is in harmony with the mystique of wilderness, this prescribed natural fire option may not be as suitable for smaller wildernesses. We have learned over the years that a prescribed natural fire program is best served when the wilderness is large enough to accommodate the growth of fires of long duration. But how do we manage the smaller wildernesses that are fire adapted? Do we continue to take the route of suppressing all fires in the smaller wildernesses, with no prescribed fire? Do we exercise the wilderness policy option of manager-ignited fires in smaller wildernesses as a better approach than simply suppressing all fires? Or is there a way to sometimes combine a lightning ignition with prescribed perimeter boundaries in the smaller wildernesses to ensure that the fire meets all objectives both in and out of wilderness? We also should consider options to develop prescribed natural fire plans for adjacent wilderness and nonwilderness lands, when management objectives are compatible on both sides of the wilderness boundary. This approach could provide larger areas that would tend to reduce the risk of long-duration fires.

It is instructive to review the distribution of wilderness sizes in regions of the West to better appreciate the large number of smaller wildernesses in the National Wilderness Preservation System. Table 1 indicates the distribution of Forest Service wildernesses by size class in Washington, Oregon, and northern California (Brown 1991).

A similar analysis for Forest Service wildernesses in the Intermountain Region produced a somewhat similar outcome regarding the distribution of wilderness sizes, as shown in Table 2.

These tables for the Northwest and Intermountain areas indicate that over 70 percent of the wildernesses are less than 100,000 acres in size. The point of these statistics to wilderness fire management is that we have already

**Table 1**—The size class distribution of Forest Service wildernesses in Washington, Oregon, and northern California

| State | Number of wildernesses <50,000 | <100,000 | >100,000 | Total |
|---|---|---|---|---|
| | - - - - - - - - - - - - - *Acres* - - - - - - - - - - - - | | | |
| Washington | 17 | 18 | 12 | 30 |
| Oregon | 27 | 32 | 7 | 39 |
| No. California | 17 | 22 | 12 | 34 |
| All | 61 (59%) | 72 (70%) | 31 (30%) | 103 |

**Table 2**—The number of Forest Service wildernesses by size class in the Intermountain Region

| State | Number of wildernesses <50,000 | <100,000 | >100,000 | Total |
|---|---|---|---|---|
| | - - - - - - - - - - - - - *Acres* - - - - - - - - - - - - | | | |
| Idaho | 1 | 1 | 2 | 3 |
| Nevada | 8 | 12 | 1 | 13 |
| Utah | 11 | 12 | 1 | 13 |
| Wyoming | 1 | 1 | 4 | 5 |
| California | 2 | 3 | 0 | 3 |
| All | 23 (62%) | 29 (78%) | 8 (22%) | 37 |

developed prescribed natural fire plans for the easier wildernesses—those wildernesses larger than several hundred thousand acres that more readily accommodate long-duration prescribed fires started by lightning. Generally, wilderness fire management plans have not been developed for wildernesses smaller than 100,000 acres in these regions. Although most, if not all, of these wildernesses are fire dependent, prescribed natural fire plans probably have not been developed because the risk of fire escape is high from these smaller wildernesses. We have learned in some of the recent drought years that even large wildernesses do not guarantee that prescribed fires will not escape to lands adjoining wilderness. What options remain for us in wilderness fire management, if wildernesses do not lend themselves to prescribed natural fires because the risk of escape is high from small or long, narrow wildernesses? The option we generally have been following in the West is one of suppressing all fires in the smaller wildernesses. This is a valid and legitimate option under many circumstances. But we should evaluate the feasibility of other options as well, if we are to meet the objective of perpetuating natural ecosystems in wilderness. We do have wilderness policy that recognizes the need for manager-ignited prescribed burning, if certain criteria are met.

The ability to perpetuate the natural disturbance regime within a reserve depends on how well the reserve is designed (Baker 1992). Baker (1992) indicated that natural disturbance regimes are probably only feasible within reserves that are:

- Several times the maximum disturbance size typical of the region.
- Located so that disturbance initiation and export zones are contained within the reserve.
- Have boundaries along natural or artificial disturbance breaks or have buffer zones within which disturbances can be controlled.

These ideal conditions often do not exist within units of the National Wilderness Preservation System. Thus, we will have to develop alternative strategies to ensure that fires play an appropriate role in fire-adapted wilderness ecosystems.

## A ROLE FOR MANAGER-IGNITED FIRES IN WILDERNESS

Wilderness policy establishes fire management objectives to permit lightning-caused fires and to reduce the risk of wildfires. Current policy also recognizes that there may be two types of prescribed fires in wilderness: those that are started by lightning and those that are ignited by managers. Qualified personnel may ignite a prescribed fire in wilderness to reduce accumulations of fuels only if necessary to reduce the risk of wildfires and if all of the following conditions are met:

- The use of prescribed fire or other fuel treatment measures outside of wilderness is not sufficient to achieve fire management objectives within wilderness.
- An interdisciplinary team of resource specialists has evaluated and recommended the proposed use of prescribed fire.
- The interested public has been involved appropriately in the decision.
- Lightning-caused fires cannot be allowed to burn because they will pose serious threats to life or property within wilderness or to life, property, or natural resources outside of wilderness.

In other words, where prescribed natural fires can achieve wilderness fire management objectives, they should be used rather than manager-ignited fires. But there are certain conditions where manager-ignited fires may be the only acceptable way to restore fire and reduce risk. We already have noted the situation where small wilderness size or wildernesses that are long and narrow can permit long-duration lightning fires to escape as wildfires onto adjacent lands. Unnatural fuel accumulations due to the exclusion of fires in some fire regimes would be another reason to gradually return more natural conditions to the regime through manager-ignited fires. The Clean Air Act and the Endangered Species Act might also set up special situations where manager-ignited fires represent the most feasible option for reintroducing fire.

Development and implementation of a prescribed fire plan for the smaller wildernesses should consider the following steps:

1. Establish wilderness fire management objectives.
2. Determine fire history, fire regimes, and fire effects.
3. Evaluate present-day naturalness of fire regimes, and the departure from historical conditions.
4. Assess the wilderness' size and shape in relation to risk of wildfire.
5. Evaluate fuels, ignitions, air quality, and endangered species.
6. Determine opportunities for mitigation outside wilderness.
7. Involve public individuals and groups.
8. Have an interdisciplinary team review and recommend from among fire management options:

- Prescribed natural fires restricted in time and space to minimize wildfire threat.
- Lightning ignition coupled with predetermined perimeters maintained by crews.
- Manager-ignited prescribed fires.
- Combining wilderness and nonwilderness lands when objectives are compatible to provide larger areas for prescribed natural fire planning.
- Interim use of manager-ignited fires to reduce unnaturally high fuel accumulations.
- Appropriate suppression response (control, contain, confine).

Those with a purist approach to wilderness management may feel uncomfortable with an option that proposes the use of manager-ignited prescribed fire. But one must question which is more natural in the management of wilderness ecosystems: attempting to exclude all fires through a suppression-only approach, or managing fire-adapted ecosystems in small wildernesses with prescribed burns ignited by managers? The latter approach will come closer to perpetuating natural ecosystems in wilderness.

As we begin to develop manager-ignited prescribed fire plans for the smaller wildernesses, it is important that we carefully consider Christensen's (1988) emphasis on natural variability:

> However, while average fire return intervals have been calculated from fire chronologies in many ecosystems, the variances about those means are very large. Furthermore, even when return intervals are regular, there is considerable variation in fire behavior among and within fires. I shall argue that such variability is an essential component of the maintenance of fire-prone ecosystems and must be a component of management programs in such ecosystems.

## CONCLUSIONS

A landscape view of fire history, fire regimes, and fire effects information has been stressed as a necessary baseline for designing and implementing wilderness fire management programs. Fire history and fire regime information is absolutely essential to the goal of maintaining natural ecosystems. The application of this baseline data in managing fire-adapted ecosystems will assist us in achieving fire effects appropriate to wilderness.

Many of the easier wilderness fire management programs already have been accomplished for the larger wildernesses like the Frank Church-River of No Return, Teton, Selway-Bitterroot, Bob Marshall, Gila, and the Boundary Waters Canoe Area. But fully three out of every four wildernesses in many areas of the West do not have fire management plans. These valuable lands are deserving of the same time and attention that have been devoted to larger wildernesses. Implementing effective fire management options for the smaller wildernesses will require special understanding and sensitivity on the part of the general public and wilderness managers. Manager-ignited prescribed fire is one way to ensure that fire once again contributes to the wildness of fire-adapted ecosystems.

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# Defining Fire and Wilderness Objectives: Applying Limits of Acceptable Change

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**Abstract**—The Limits of Acceptable Change (LAC) planning process was developed to help define objectives for recreation management in wilderness. This process can be applied to fire in wilderness if its conceptual foundation is broadened. LAC would lead decision makers to identify a compromise between the goal of allowing fire to play its natural role in wilderness and various constraints, such as threats to life and property. Fires would be allowed to burn as prescribed natural fires as long as preestablished criteria related to these constraints were not exceeded.

People interested in the management of fire in wilderness have recognized the need for specific management objectives for many years. They have debated whether objectives should be defined in structural or process terms (Bancroft and others 1985; Bonnicksen 1985) and have questioned the desired precision of objectives (Vale 1987). However, they have had little success in writing specific objectives for fire in wilderness.

Management of recreation in wilderness changed recently with development of the Limits of Acceptable Change (LAC) planning process (Stankey and others 1985). While it is still too early to evaluate the effect of this process on wilderness quality, the process has clearly changed the nature of wilderness management. The LAC process is being implemented in scores of wilderness areas and has been recommended in both a GAO report (U.S. GAO 1989) and in legislation recently introduced in Congress (H.R.4325, 102d Congress).

The enthusiastic response of wilderness managers to LAC as a means of dealing with recreation issues raises the question, can it be applied to other wilderness management issues—such as fire? This paper was spurred by interest in that question. Purposes of this paper are to (1) reiterate some of the reasons why defining specific objectives is critical to managing fire in wilderness, (2) describe how LAC has been used to develop specific objectives for recreation management in wilderness, and (3) explore what this experience suggests about defining objectives for fire management in wilderness. A final purpose—which only surfaced as this paper developed—is to assess the general utility of the LAC process as a planning tool for wilderness management.

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## GOALS, OBJECTIVES, AND STANDARDS

Wilderness management goals, as defined in the Wilderness Act, stress protection and management "so as to preserve...natural conditions." Other phrases in the Act that are useful in defining goals include reference to "primeval character and influence," "wilderness character," and "unimpaired condition." These phrases imply that wilderness managers are to maintain or restore the wilderness conditions and processes that existed prior to the period of "increasing population," "expanding settlement," and "growing mechanization" that spurred Congress to pass the Wilderness Act.

Many studies have demonstrated the importance of fire in shaping the character of most wilderness landscapes (Kilgore and Heinselman 1990). Clearly, wilderness managers cannot meet the goal of preserving natural conditions without allowing fire to operate in a natural manner. Although it might be possible to maintain the structural elements of a natural landscape without natural fire (for example, by using silvicultural treatments or prescribed burns), the fire processes themselves would no longer be natural.

Unfortunately, the goal of restoring fire to its natural role in wilderness is not entirely possible because the goals of the Wilderness Act are not paramount in society. Instead, wilderness goals compromise and are compromised by other goals, particularly concerns for (1) clean air, (2) wilderness visitor safety, (3) preservation of cultural resources, (4) preservation of threatened and endangered species, (5) protection of commercial operations, and (6) protection of land and property. Even the Wilderness Act recognizes the need to control fire in wilderness, stating that "such measures may be taken as may be necessary in the control of fire...subject to such conditions as the Secretary deems desirable." Achievement of wilderness goals is also constrained by (1) the accumulated effects of decades of fire suppression, (2) suppression of fires on lands adjacent to wilderness, and (3) undesirable ignitions that occur within and adjacent to wilderness.

Natural resource professionals have traditionally relied on professional judgment when compromising among goals. The advantage of this tradition is flexibility; the disadvantage is implicit and subjective decision making that is no longer acceptable to the public. Given the competing demands our pluralistic society places on resources, the public requires explicit and objective decision making and opportunities for public involvement. Specification of management goals, objectives, and standards is one of the foremost requisites for explicit decision making that is accessible to the public.

Goals, objectives, and standards can serve many purposes. In this paper I focus primarily on the utility of objectives and standards for (1) defining desired conditions related to individual goals and (2) defining a compromise between conflicting individual goals. Let me begin by defining the terminology I use.

First, the distinctions between goals, objectives, and standards are neither clear nor defined in a consistent manner. Distinctions usually relate to the specificity and attainability of statements of intent (Hendee and von Koch 1990). Goals are usually general and lofty statements—impossible dreams. They are relatively easy to articulate, but they are of limited value operationally. Objectives are more specific but may or may not be attainable. The term "standard" is usually reserved for statements of intent that are both specific and attainable. Thus standards are a type of objective. All standards are objectives, but not all objectives are standards.

Second, wilderness objectives can be written to specify preservation of certain conditions (implying structural considerations) or certain processes. Debate over the preferred approach is important but incidental to this paper. For convenience, I will use the term "condition," without any implication that structure-based approaches are preferable to process-based approaches.

## Desired Conditions

Management objectives are useful as targets for management programs. For each goal or management concern it should be possible to write specific objectives that define what a management program is trying to accomplish. These objectives can relate to such issues as maintaining natural conditions, protecting life and property from fire, or maintaining clean air. Examples of desired-condition objectives might include "to see that the number, size, and intensity of fires approximates those that occurred under a natural fire regime" or "to see that no lives are lost and no property is destroyed as a result of fire."

These objectives guide managers as they make decisions about how to respond to an ignition or as they develop prescribed burn programs or other programs that will influence wilderness fire and its effects. For this purpose, objectives should be stated in terms of desired conditions or results. They should specify the ideal, whether this ideal is attainable or not. Statements should be as specific and unambiguous as possible.

## Compromise

The problem with desired-condition objectives is that they may not be attainable, particularly if they conflict with other objectives. Consequently, wilderness managers must often balance conflicting individual goals. Objectives can serve the role of explicitly defining the compromise between opposing goals. For example, Kilgore and Heinselman (1990) stated that the general management objective for a wilderness fire program is "to restore fire to its natural role in the ecosystem to the maximum extent consistent with safety of persons, property, and other resources." This statement identifies both natural fire and safety as goals and acknowledges that they conflict with each other. It also establishes the relative importance of these two goals, by stating that safety concerns will constrain the extent to which "naturalness" goals are achieved. The goal of natural fire will ultimately be compromised if safety concerns become too severe.

As written, this objective is probably attainable. The objective states an acceptable compromise condition, not a desired condition. The objective is not "natural fire"; the objective is fire that is "as natural as possible," given other constraints. The problem with this objective is that it is not specific enough. As written, it would not be possible to evaluate whether or not the objective has been met. Objectives that define compromises between goals need to be both specific (or measurable) and attainable.

# RECREATION MANAGEMENT AND LAC

Wilderness managers have always faced the challenge of wrestling with conflicting goals. One of the most troublesome dilemmas has been the conflict between recreation use and preservation of natural conditions in wilderness. The Wilderness Act specifies that natural conditions should be preserved, but it also states that wilderness "shall be administered for the use and enjoyment of the American people." Because use inevitably causes some deviation from natural conditions, both goals cannot be attained.

Concern over this dilemma initially surfaced more than 50 years ago. Early students of the problem suggested that the solution was to restrict use to an area's recreational saturation point (Sumner 1942), or carrying capacity. Further research, however, made it clear that an area's carrying capacity can only be defined in relation to an area's management objectives (Lime and Stankey 1971). Thus there was early recognition that the initial step in dealing with the conflict between recreational use and wilderness preservation must be the development of specific management objectives.

For decades little progress was made in defining specific management objectives for wilderness. The objectives that existed in most plans were neither specific nor attainable. Many plans had objectives such as "to maintain natural vegetative conditions" and "to provide outstanding opportunities for primitive and unconfined recreation." In the meantime, management implemented programs that, in effect, established a compromise between competing objectives. For example, some managers attempt to provide more-natural conditions by reducing amount of use. However, this reduces use and enjoyment of wilderness, violating one of the goals of the Wilderness Act. Without specific objectives, compromises are implicit and subjective, and it is seldom possible to objectively evaluate the relative costs and benefits of management programs.

## The LAC Process

The Limits of Acceptable Change (LAC) process was developed in an attempt to help managers develop specific objectives and base their management program on these objectives. It was initially conceived as a way to deal with the so-called "carrying capacity issue." The basic premise behind the process was: to allow some recreational use of wilderness, some undesirable impact would have to be accepted. The key, then, is to define the optimal balance between the goals of allowing recreational use and preserving wilderness conditions.

The LAC process, in its simplest form, consists of four interrelated steps: (1) establishing quantitative standards that define acceptable wilderness conditions; (2) comparing existing conditions to these standards for acceptable conditions; (3) developing management strategies to deal with problem situations, where current conditions do not meet standards of acceptability; and (4) periodic monitoring of conditions to reevaluate whether or not standards are being met.

To illustrate how the process works, consider the conflict between recreation use and preservation of natural conditions, particularly at wilderness campsites. Where managers choose to allow high levels of recreation use, campsite impacts will also be high. Where they choose to keep campsite impacts to minimal levels, recreation use will have to be kept to low levels. Most situations should lie between these extremes; the key is to define a balance.

A fundamental premise of the LAC process is that primary attention must be given to wilderness conditions and the actions needed to protect or achieve acceptable conditions (Stankey and others 1985). In the Bob Marshall Wilderness, maximum acceptable levels of campsite density and campsite impact have been specified (Stankey and others 1990). For example, standards for one management zone state that there will be no more than one highly impacted campsite per square mile. This and other standards define the balance between use and preservation in an explicit way. If campsite conditions are "worse" than standards, management is obliged to improve conditions, even if this means restricting recreation use. Conversely, if conditions are "better" than standards, management should not restrict recreation use simply to prevent further deterioration of conditions. Actions to prevent campsite deterioration would be appropriate only if they did not conflict with other management objectives (for example, teaching a low-impact ethic would be appropriate).

Although the people who developed the LAC process—of whom I am one—were not explicit about this, the aim of LAC is to define the optimum balance between conflicting goals. The process in its most generic form involves: (1) recognizing the conflict between goals; (2) establishing that one goal will constrain the others; and (3) defining minimally acceptable conditions (LAC standards) for this constraining goal. Where there is conflict between goals, neither goal can be maximized, but through the LAC process the trade-off between goals is optimized. Moreover, the standards make that trade-off explicit.

This approach is not an uncommon one in our society. An example involves the problem of winter air pollution in Montana's Missoula Valley. People like to heat their homes with wood, but wood burning causes a significant air pollution problem. Ideally, people would be free to burn wood whenever they wanted and also be able to breathe clean air in winter. Unfortunately, this is not possible. Missoula County officials decided that concern for clean air would constrain wood burning, and they established an air quality standard. Now, people are allowed to freely burn as long as this air quality standard is not violated. Whenever air quality is worse than the standard, the freedom to burn wood is removed. Neither goal is maximized. Missoula air is not clean and woodburners are not free to burn whenever they want. However, the minimally acceptable air quality standard optimizes the two goals in an explicit manner. This is exactly analogous to the LAC process.

## What Has LAC Accomplished?

So far, the LAC process has been used primarily to deal with recreation issues in wilderness. It has enabled managers to develop specific, measurable standards for some critical recreation concerns, such as campsite impacts and encounters between recreation users. These standards perform the important role of defining the optimum balance between conflicting goals. They provide explicit criteria for deciding when recreation use will be restricted and when it will not be restricted. This assures the maintenance of conditions that are at least minimally acceptable, without unduly restricting recreation use.

What the LAC process does not provide are specific management objectives that define desired conditions for individual goals. For example, the desired level of campsite impact in the Bob Marshall Wilderness is not one highly impacted campsite per square mile (the LAC standard). This is the condition that is considered minimally acceptable to allow recreation use. The desired condition would probably be no campsite impact at all. Management should seek to achieve these desired conditions; however, they should not compromise other goals (such as allowing recreation use) if conditions are at least acceptable.

In sum, the only kinds of objectives that the LAC process provides are statements of minimally acceptable conditions (standards) for the goals that constrain other goals. Desired conditions are not specified for any goals and minimally acceptable conditions are not defined for constrained goals. This suggests some shortcomings of the LAC process as a general planning framework. Its benefits, however, are substantial.

## LAC STANDARDS FOR FIRE IN WILDERNESS

How can the LAC concept be applied to fire in wilderness? Initially, I supposed that the analogous approach would be to write quantitative, attainable standards for natural conditions. Although this approach has been strongly advocated by some (Bonnicksen 1985), previous attempts to do this have been frustrating because (1) there is little consensus about what "natural" is (Kilgore

and Heinselman 1990) and (2) "natural" conditions are always changing (Christensen 1988). My analysis suggests that the LAC process may be more helpful in defining compromise than in establishing naturalness objectives.

## Compromise Standards

Standards that define the compromise between opposing goals could be very useful in managing fire in wilderness. Of the many conflicting goals that face fire managers, perhaps the conflict between preservation of natural conditions and the safety of people and property is most compelling. How this conflict is resolved determines when fires are allowed to burn in wilderness and when they are suppressed. I will focus on this particular conflict as an example, but LAC could also be applied to other goals that constrain natural fire. These other goals may be much more constraining in smaller wildernesses where prescribed natural fire programs may be impractical.

The LAC approach would involve deciding which of these two goals is the constraining one and then defining minimally acceptable conditions for that goal. In thinking about the conflict between preservation of natural conditions in wilderness and concern about the safety of people and property, it seems clear that safety is the constraining goal and natural conditions is the constrained goal. Kilgore and Heinselman's (1990) objective (paraphrased) stated that fire should be restored to its natural role to the "maximum extent consistent" with maintaining an acceptable level of safety of life, property, and other resources. Clearly, they implied that safety will constrain concern for allowing fire to play its natural role. Therefore, this compromise must be defined by specifying an acceptable level of safety—not an acceptable deviation from natural conditions. Limits of acceptable change could be defined for the role of fire, but they would never be met if achieving them entailed an unacceptable degree of risk.

This suggests that what is needed are quantitative, unambiguous statements of minimum levels of safety (or maximum levels of risk) associated with allowing natural fires to burn in wilderness. These preestablished explicit criteria (standards) would dictate when fires are to be suppressed in wilderness. Most lightning fires would be allowed to burn as a part of the wilderness landscape and only where risks exceed acceptable levels would these fires be declared wild and managed accordingly. Similar standards of acceptability could also be written for other conflicting goals such as levels of smoke, threats to threatened and endangered species, and disruption of recreation. Lightning fires could be allowed to burn as prescribed natural fires as long as preestablished standards were not exceeded.

For example, given a concern about the threat of fire to private property outside the wilderness, we might develop an indicator of the likelihood of a fire or ignition escaping from the wilderness. I'm not certain how best to measure this. Perhaps models could be developed that would incorporate such factors as fuel levels, weather, ignition location, time of year, and available manpower, and predict this "likelihood of escape." Perhaps we would be willing to accept a 20 percent risk of a fire burning outside wilderness, but no more. This would be made explicit in a standard. Then we would be in a position to allow new ignitions to burn as long as the models predicted a likelihood of escape of less than 20 percent. New ignitions or prescribed fires would be suppressed whenever the 20 percent standard was exceeded.

Specific standards would have at least four positive effects. First, compromise would occur within a more visible socio-political context and established standards would be explicit and predetermined. Second, specific standards would ensure that fires are suppressed when they are likely to cause unacceptable problems. Third, the goal of naturalness in wilderness would not be unduly compromised because fires would be allowed to burn in all cases where their effects are likely to be acceptable. Fourth, the personal biases of managers, whatever their commitment to naturalness goals in wilderness or their aversion to risk, would have less influence on wilderness fire programs.

## Naturalness Objectives

The LAC process only requires that standards be written for constraining goals. Because naturalness is the constrained goal in this case, the LAC process would be silent about naturalness goals. Nevertheless, some objectives related to naturalness are clearly needed. In my opinion, naturalness objectives would be most useful as statements of desired conditions even if these desired conditions are impossible to attain. These statements could be used to evaluate the appropriateness of alternative management strategies and, secondarily, to evaluate performance.

Attempts to define desired-condition objectives for fire and its effects in wilderness have been controversial. Some have called for objectives based on structural conditions (Bonnicksen 1985); others prefer process-oriented objectives (Bancroft and others 1985). Others suggest that the suitability of structural and process goals will vary with fire regime and wilderness size (Agee and Huff 1986). Christensen (1988) suggested that objectives should not be written for maintenance of some average or optimal condition, but rather for some degree of variability or heterogeneity.

These debates are relevant and the questions must be resolved. However, if naturalness objectives are not strictly attainable it may not matter how the issue is resolved. The naturalness of wilderness and parks will be determined more by the levels of risk to personal safety and property that society is willing to accept than by naturalness objectives developed by scientists. Consequently, highly precise definitions of naturalness are desirable but not critical.

# CONCLUSIONS

Specific objectives and standards can be useful in defining a compromise between conflicting goals and in defining desired conditions to guide management. The preceding analysis suggests that the LAC process is helpful for defining a compromise but not for defining desired conditions. This suggests something about the types of wilderness fire objectives that will be most useful. It also suggests a need to broaden the LAC concept if it is to be more generally useful.

## Wilderness Fire Objectives

The most critical need is for quantitative, attainable standards that specify criteria for making such decisions as whether or not fires need to be suppressed and where and when management ignitions should be used. This could be accomplished by establishing LAC standards for such constraining goals as threats to life and property, visitor protection, smoke production or visibility, disruption of threatened and endangered species, and disruption of recreation. These standards would specify to what extent these goals could be compromised before it would be necessary to compromise wilderness fire goals. Specification of such standards would lead to more consistent and responsive fire management in wilderness.

Within the constraints that such limits will impose, managers should attempt to maximize restoration of fire's natural role in the ecosystem. Objective statements of desired conditions and outcomes will improve these attempts, particularly if they are precise and unambiguous. Therefore, researchers and decision makers should attempt to work toward more precise definitions of naturalness. In the interim, however, even general statements of desired conditions should be sufficient to allow managers to make appropriate decisions about alternative actions.

## Reconceiving LAC

LAC concepts must be expanded if they are to be applied broadly beyond the carrying capacity issue for which LAC was originally formulated. Considerable confusion stems from the original report of Stankey and others (1985). The terminology used in that report was not always precise enough. In particular, the notions of desirable conditions and acceptable conditions were used interchangeably, even though it is clear that standards refer to minimally acceptable conditions. In addition, no generic model of the LAC process is presented. The process described is specific only to the carrying capacity dilemma.

These shortcomings could be overcome relatively simply. First, a more generic model of how LAC operates should be developed. In my opinion, it should be explicitly stated that the LAC process involves establishing a compromise between constraining and constrained goals. Standards of acceptability are then defined for the constraining goal. Standards could be developed for wilderness conditions (as implied in Stankey and others 1985) or for goals other than wilderness condition (such as protecting property from fire). This would require a broader interpretation of the LAC process.

In addition to defining these standards of acceptable conditions for the constraining goal, it is also important to define desired conditions for all critical goals and management concerns. These are needed during the steps in the process when management strategies are conceived and implemented. They are also needed in situations where conditions are better than acceptable but worse than desired. Currently, the LAC process does not produce statements of desired conditions. These could be readily included in the process during its early stages, particularly in the development of opportunity class descriptions.

Even with these changes, there may be many wilderness management issues for which LAC is an inappropriate planning framework. Given that LAC is a process for optimizing the balance between conflicting goals, the LAC process does not provide efficient solutions in situations where there is no conflict between goals. Where there is no conflict, objectives should define desired conditions rather than the minimally acceptable conditions that are at the core of the LAC concept. LAC also will not work in situations where planners are unwilling or unable to say that one goal constrains another. This follows from the practice of only writing LAC standards for constraining goals. If they were written for several goals that conflicted with each other there would be situations where it was impossible to meet all standards.

LAC has become a useful and popular tool in planning for the management of recreation in wilderness. From this analysis, it appears that the process could also contribute to planning for the management of fire in wilderness. More critical evaluation and development of the LAC process would facilitate both expanded LAC applications and better application of LAC to recreation. It would also avoid frustrating efforts to apply LAC in situations where it is not well suited.

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# Comparing the Selway-Bitterroot Fire Program With Presettlement Fires

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**Abstract**—Area burned and smoke emissions were compared between the presettlement period (before 1935) and the recent period (1979-90) of prescribed natural fire in the Selway-Bitterroot Wilderness. Presettlement area burned was estimated to be 1.7 times that during the recent period. By fire-severity classes, stand-replacement fire was 1.5 times greater and nonlethal understory fire 1.9 times greater during presettlement. Smoke emission estimates were 1.3 times greater during presettlement. Duration of smoke events since 1960 in downwind valley towns was determined. No difference in smoke occurrence was observed between periods managed under a full suppression policy (1960-71) and prescribed natural fire policy.

The Wilderness Act of 1964 set forth a goal of preserving natural conditions by allowing the forces of nature to operate. Recognizing that fire had been kept from playing a natural role in wilderness areas, the Forest Service, U.S. Department of Agriculture, and National Park Service, U.S. Department of the Interior, began a program about 1970 to reintroduce fire into some large park and wilderness areas. By 1979, such a program was implemented over the entire Selway-Bitterroot Wilderness (SBW) in northern Idaho and western Montana.

In evaluating the prescribed natural fire program in the SBW, important questions to answer for today's managers are: (1) How well have the objectives of restoring natural fire been met, and (2) what are the smoke impacts of the prescribed natural fire program? The purpose of this paper is to report on results of a study that compared area burned, fire severity, and smoke production from fires during recent (1979-90) and presettlement (before 1935) periods. The term "presettlement" is commonly used in fire history studies to refer to the period before fire suppression became effective.

## METHODS

The study was conducted throughout the 1,300,470-acre SBW, which contains a diversity of forest types. The methods, described in detail by Brown and others (in review) and Brown and Bradshaw (in review), are summarized as follows:

1. Major vegetation types were classified into fire regime types based on elevation, aspect, and landform position. The following fire regime types were recognized. They were named for the characteristic seral species followed by the climax species:

*Lower elevation types*

a. Ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii* var. *glauca*)
b. Shrubfield-conifer
c. Douglas-fir/grand fir (*Abies grandis*)
d. Western redcedar (*Thuja plicata*)

*Upper elevation types*

e. Lodgepole pine (*Pinus contorta*)/subalpine fir (*Abies lasiocarpa*)
f. Engelmann spruce (*Picea engelmannii*) Douglas-fir/subalpine fir
g. Whitebark pine (*Pinus albicaulis*)/subalpine fir
h. Alpine larch (*Larix lyallii*)-Engelmann spruce/subalpine fir

A GIS System was used to map fire regime types by utilizing DEM (Digital Elevation Model) and LANDSAT Multispectral Scanner data. Fire regime types will be referred to henceforth by the seral or first-named species.

2. Presettlement fire intervals were determined for stand-replacement and nonlethal understory fires by sampling in 77 stands using techniques of Barrett and Arno (1988). Annual area burned was calculated as area of a fire regime type divided by the fire intervals.

3. Boundaries of all recent period fires 10 acres and larger were mapped on topographic maps by 10-day calendar burning periods, then digitized. Area burned by 10-day period and fire regime type was then computed.

4. Fire severity was estimated for each fire by 10-day periods as percentage of area within each fire's perimeter experiencing crowning fire, lethal underburning, nonlethal underburning, and no burning. Estimates were made by Jack Puckett, an experienced fire behavior specialist, who examined aerial photographs, made aerial observations, consulted others familiar with the fires, and made comparisons with similar fires where severity was known. Stand-replacement fire was equated with crowning and lethal underburning. Understory fire was equated with nonlethal

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underburning and nonburned patches. In this paper "understory fire" refers to fire that is nonlethal to most of the overstory trees.

5. Fuel consumption was estimated for each fire regime type by first constructing fuel models consisting of loadings for 11 fuel components based on data from the SBW (Brown and Bevins 1986; Brown and Bradshaw, in review). Loadings were multiplied by the percentage of fuel consumption and emission factors to estimate smoke production. Percentage fuel consumption was estimated by flaming and smoldering combustion for each component based on predictive relationships (Brown and others 1985; Norum 1976; Ottmar 1983).

6. Smoke production was estimated by multiplying fuel consumption times emission factors (mass of emission produced per mass of fuel consumed) derived from research by Ward and Hardy (1991). The emission factors used were 18 lb/ton for flaming combustion and 46 lb/ton for smoldering combustion.

7. Occurrence of smoke events in the Bitterroot Valley was based on observations at the Missoula, MT, airport, climatic summaries from NOAA Climate Analysis Center, and past issues of the Ravalli Republic newspaper, Hamilton, MT (Bradshaw 1993).

# PRESETTLEMENT FIRES

The characteristics of presettlement fire regime types are summarized in table 1. Analysis of stand age-class structure and fire history from sample plots revealed that, at lower elevations, presettlement ponderosa pine stands were open or parklike and dominated by mature ponderosa pine trees with clear boles. The lowest branches were high above the ground, reflecting the history of frequent, nonlethal surface fires. Shrubfield vegetation occurred primarily on warm, dry slopes, apparently resulting from previous stand-replacement fires repeated at relatively close intervals. The Douglas-fir stands were primarily even-aged, but presence of some fire-scarred trees indicated that stand-replacement fire was often patchy. The western redcedar stands in canyon bottoms were uneven-aged and subject to long fire intervals.

At upper elevations, the lodgepole pine and Engelmann spruce types were primarily even-aged. Stand-replacement fire was the predominant fire severity in all types. On gently sloped, dry lodgepole pine sites, however, nonlethal understory fires also occurred. Whitebark pine and alpine larch types formed a mosaic of conifer stands and sparsely vegetated rocklands. Nonlethal fires occurred throughout the whitebark pine type.

Table 1—Characteristics of fire regime types in the SBW

| Fire regime type | Percentage of SBW | Fire intervals (yr) Stand replace | | Underburn, mixed | | | Fire severity[1] |
|---|---|---|---|---|---|---|---|
| | | *Mean* | *n* | *Mean* | *n* | *St. dev.* | |
| **Lower elevation** | | | | | | | |
| Ponderosa pine/ Douglas-fir (PP) | 12 | | | 22 | 11 | 7.7 | Nonlethal |
| Shrubfield-conifer (SH) | 2 | 54 | 1 | — | — | — | Lethal |
| Douglas-fir/ grand fir (DF) | 10 | 119 | 13 | — | — | — | Lethal and Mixed |
| Western redcedar (WRC) | 3 | 197 | 7 | — | — | — | Lethal |
| **Upper elevation** | | | | | | | |
| Lodgepole pine/ subalpine fir (LP) | 43 [2](3) | 112 | 9 | 47 | 6 | 20 | Lethal and Mixed |
| Engelmann spruce-Douglas-fir/ subalpine fir (ES) | 11 | 166 | 9 | — | — | — | Lethal |
| Whitebark pine/ subalpine fir (WBP) | 3 (3) | [3]180 | 5 | 56 | 5 | 17 | Mixed |
| Alpine larch-Engelmann spruce/ subalpine fir (AL) | 6 (2) | [3]166 | 9 | — | — | — | Lethal |
| Total | 90 (8) | | | | | | |

[1]"Nonlethal" to most overstory trees, "lethal" to most overstory trees, or "mixed" mortality among the overstory.
[2]Numbers in parentheses are percentage of rocklands. Alpine tundra, water, and other minor types comprised the remaining 2 percent of the SBW.
[3]Stand-replacement fire interval data for the Engelman spruce type were assumed to represent the alpine larch type.

Table 2—Occurrence of wildfires and prescribed natural fires (Rx) in the SBW by two size classes based on Forest Service Northern Region fire statistics

| Fire regime groups | Less than 10 acres | | | 10 acres and greater | | |
|---|---|---|---|---|---|---|
| | Wild | Rx | Percentage Rx | Wild | Rx | Percentage Rx |
| Lower elevation | 232 | 97 | 29 | 27 | 23 | 46 |
| Upper elevation | 232 | 108 | 32 | 46 | 17 | 27 |
| Rockland | 0 | 51 | 100 | 0 | 13 | 100 |
| Total | 464 | 256 | 36 | 73 | 53 | 42 |

## RECENT-PERIOD FIRES

For all fires including those less than 10 acres in size, 64 percent were managed as wildfires and 36 percent as prescribed natural fires (table 2). Prescribed natural fires were lightning-caused fires allowed to burn during prescribed conditions (Tomascak 1991). Rocklands, which occupy 8 percent of the SBW, had 21 percent of the prescribed natural fires. Approximately 90 percent of the wildfires were managed using a contain or confine strategy that employs limited suppression tactics to keep fires from escaping wilderness boundaries or threatening property (Benedict and others 1991; Wakimoto 1989).

During the 12-year period, fire covered just over 150,000 acres (table 3), of which 60 percent was in the ponderosa pine and lodgepole pine fire regime types. Fires during the severe 1988 fire season were responsible for 39 percent of the area burned.

Prescribed natural fire accounted for 44 percent of the total area burned (table 3). The proportion of area burned by prescribed natural fire was noticeably greater in the lower elevation fire regime types. The 1988 data were removed to show the effect of a single severe fire year on the burned area statistics. Excluding 1988, prescribed natural fire was responsible for 73 percent of the total area burned.

In the upper elevation fire regime types, which occupy 71 percent of the SBW, stand-replacement fire accounted for 72 percent of the total area burned (table 4). In the lower elevation fire regime types, excluding the shrubfield type because it differs from other types in having no overstory trees, stand-replacement fire accounted for 29 percent of the area burned. The severe fire year of 1988 resulted in more stand-replacement fire than in other years. In 1988, stand-replacement fire accounted for 78 percent of the area burned for upper elevation types and 45 percent for the lower elevation types.

Not all stand-replacement fire was due to crowning fire. In fact, 60 percent of stand-replacement fire for all regime

Table 3—Area burned (acres) by fire regime type and whether managed as prescribed fire (Rx) or wildfire

| Fire regime | Wildfire | Rx | All fires | Percentage Rx |
|---|---|---|---|---|
| **Lower elevation** | | | | |
| PP | 7,788 | 26,713 | 34,501 | 77 |
| SH | 1,513 | 2,447 | 3,960 | 62 |
| DF | 6,736 | 12,085 | 18,821 | 64 |
| WRC | 620 | 3,986 | 4,606 | 87 |
| **Upper elevation** | | | | |
| LP | 40,927 | 14,549 | 55,476 | 26 |
| ES | 10,000 | 1,803 | 11,803 | 15 |
| WBP | 1,880 | 754 | 2,634 | 29 |
| AL | 6,088 | 948 | 7,036 | 13 |
| Rockland | 7,880 | 3,337 | 11,217 | 30 |
| Total | 83,432 | 66,622 | 150,054 | 44 |

Table 4—Fire severity as percentage of area burned for all fires 1979-90 by individual fire regime types. Stand replacement includes crown fire and lethal underburn. Understory fire includes nonlethal underburn and nonburned patches

| Fire regime | Crown fire | Lethal underburn | Nonlethal underburn | Nonburned | Stand replacement | Understory fire |
|---|---|---|---|---|---|---|
| **Lower elevation** | | | | | | |
| PP | 8 | 18 | 56 | 18 | 26 | 74 |
| SH | 0 | 56 | 13 | 31 | 56 | 44 |
| DF | 11 | 25 | 39 | 25 | 36 | 64 |
| WRC | 1 | 19 | 46 | 34 | 20 | 80 |
| **Upper elevation** | | | | | | |
| LP | 38 | 39 | 11 | 12 | 77 | 23 |
| ES | 35 | 36 | 16 | 13 | 71 | 29 |
| WBP | 18 | 52 | 16 | 14 | 70 | 30 |
| AL | 24 | 49 | 11 | 16 | 73 | 27 |
| Rockland | 12 | 42 | 10 | 36 | 54 | 46 |

types was due to lethal underburning and the other 40 percent was due to crowning.

Estimated fuel consumption averaged 205,600 tons/yr from the SBW, which resulted in an average of 3,309 tons/yr of total particulate matter. Fuel consumption rates varied from approximately 8 tons/acre for the whitebark pine type to 43 tons/acre for the redcedar type.

The distribution of fuel consumption and associated smoke emissions, like area burned, was highly skewed (fig. 1). A few years accounted for most of the fire effects. Approximately 3 out of 10 years accounted for 80 percent of the total emissions. Nearly half of the total emissions during the recent period were produced in a single year, 1988. In fact, almost 40 percent of the 1988 emissions were produced by wildfires during one 10-day period.

Although 1988 was a severe fire season, emissions from 53,100 burned acres in the SBW were less than estimated emissions from the 24-hour 55,900-acre Sundance Fire in 1967 (Ward and Hardy 1991). In another comparison, emission rate of total particulate matter for all SBW fires was estimated at 529 lb/acre, substantially less than the 896 lb/acre estimated for the 94,000-acre Silver Fire (1987) in southwestern Oregon (Einfeld and others 1991). Fuel models for the forest types in the Silver Fire reflected considerably greater woody fuel loadings than the fuel models representing the SBW.

Records of valley smoke were available for a 31-year period. During that time smoke was recorded in either the Missoula or Bitterroot Valley on an average of 4 out of 10 years (Bradshaw 1993). Smoke was recorded for 50 percent of the years from 1960 to 1971, a period of full suppression (fig. 2). For the prescribed natural fire period, smoke was recorded for less than 50 percent of the years. The limited data suggest no real difference in smoke events between policies of full suppression and prescribed natural fire.

The duration of reported smoke conditions in the valleys for the 31-year period ranged from 2 to 10 days. Extreme

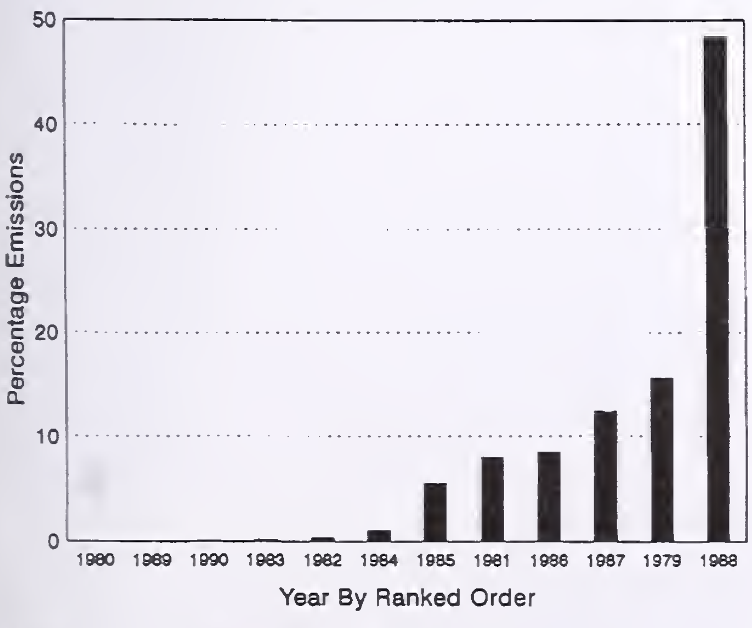



**Figure 1**—Production of total particulate matter as a percentage of emissions from all fires in the SBW by year and rank order.

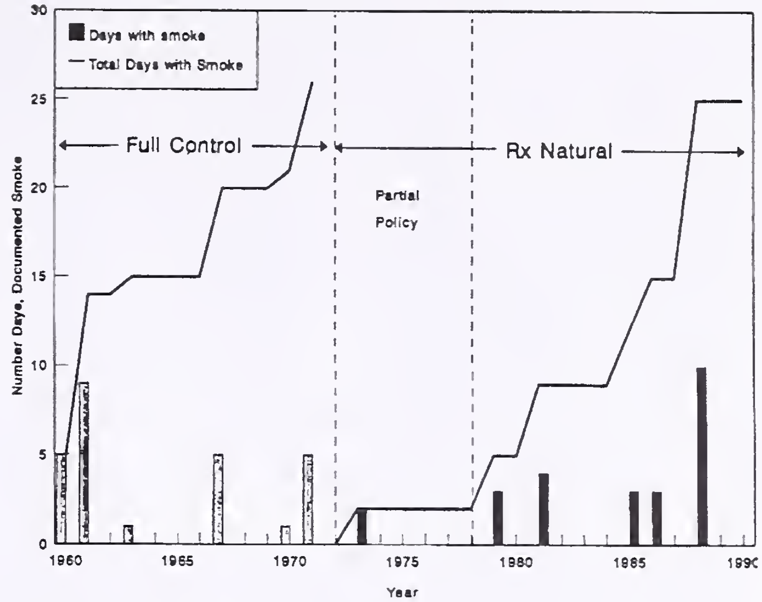



**Figure 2**—Number of days with valley smoke under programs of full suppression and prescribed natural fire. From 1972 to 1975 only the Whitecap area was approved for prescribed natural fire.

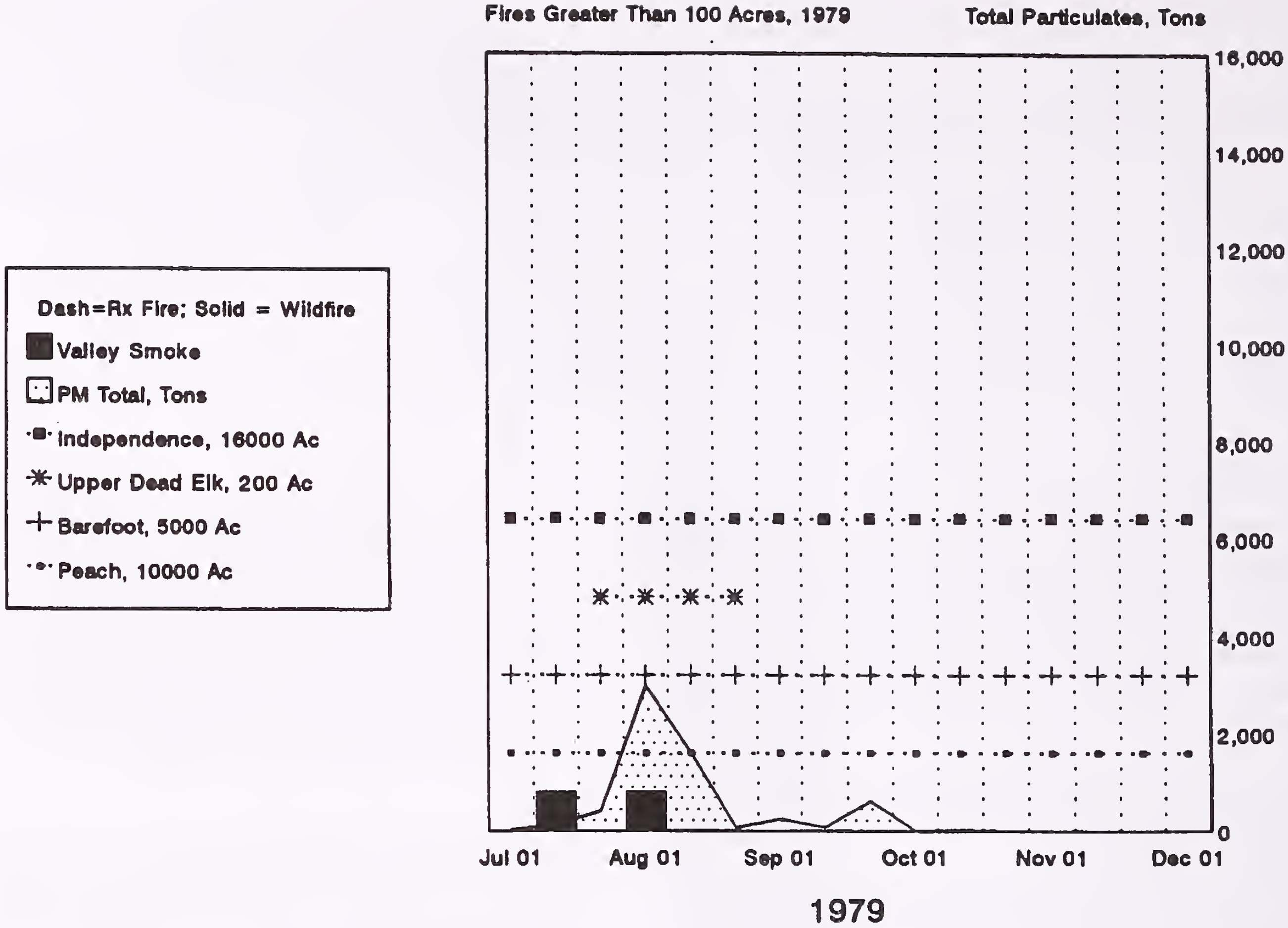
smoke impacts, characterized by 5 to 10 days of extended lingering smoke with visibilities dropping below 5 miles, occurred during 2 years, 1961 and 1988. Thus, extreme smoke events from wilderness fires occurred on an average of 1 out of 15 years. In both years, all fires contributing significant smoke were managed as wildfires.

The nature of emission production during the course of a fire season and valley smoke events are shown in figure 3 for the two recent-period years of greatest fire activity. The duration of major fires was plotted and shows that most of the emissions were generated during a relatively short period of the fire when extremely high burning conditions prevailed.

The probability of a valley smoke event is 70 percent for 2,000 tons of emissions produced during a 10-day period (Brown and Bradshaw, in review). This probability increases at higher emission rates. Valley smoke events occurred when emissions exceeded the 2,000-ton level during both years illustrated in figure 3. Occasionally, valley smoke events occur at low rates of emissions production as also shown in figure 3. But in this situation the smoke events tend to be shorter in length and have less impact on visibility than smoke events occurring during periods of high emissions production.

## PRESETTLEMENT VS. RECENT

Presettlement annual area burned can be compared with the recent-period average annual area burned to indicate how closely the wilderness fire management program has matched presettlement fire activity. For the entire SBW, area burned during presettlement was 1.7 times greater than during the recent period (table 5). The difference between presettlement and recent periods was slightly less for lower elevation fire regime types than for upper elevation types. For stand-replacement fire, presettlement area burned was 1.5 times greater and for understory fire it was 1.9 times greater than recent area burned.



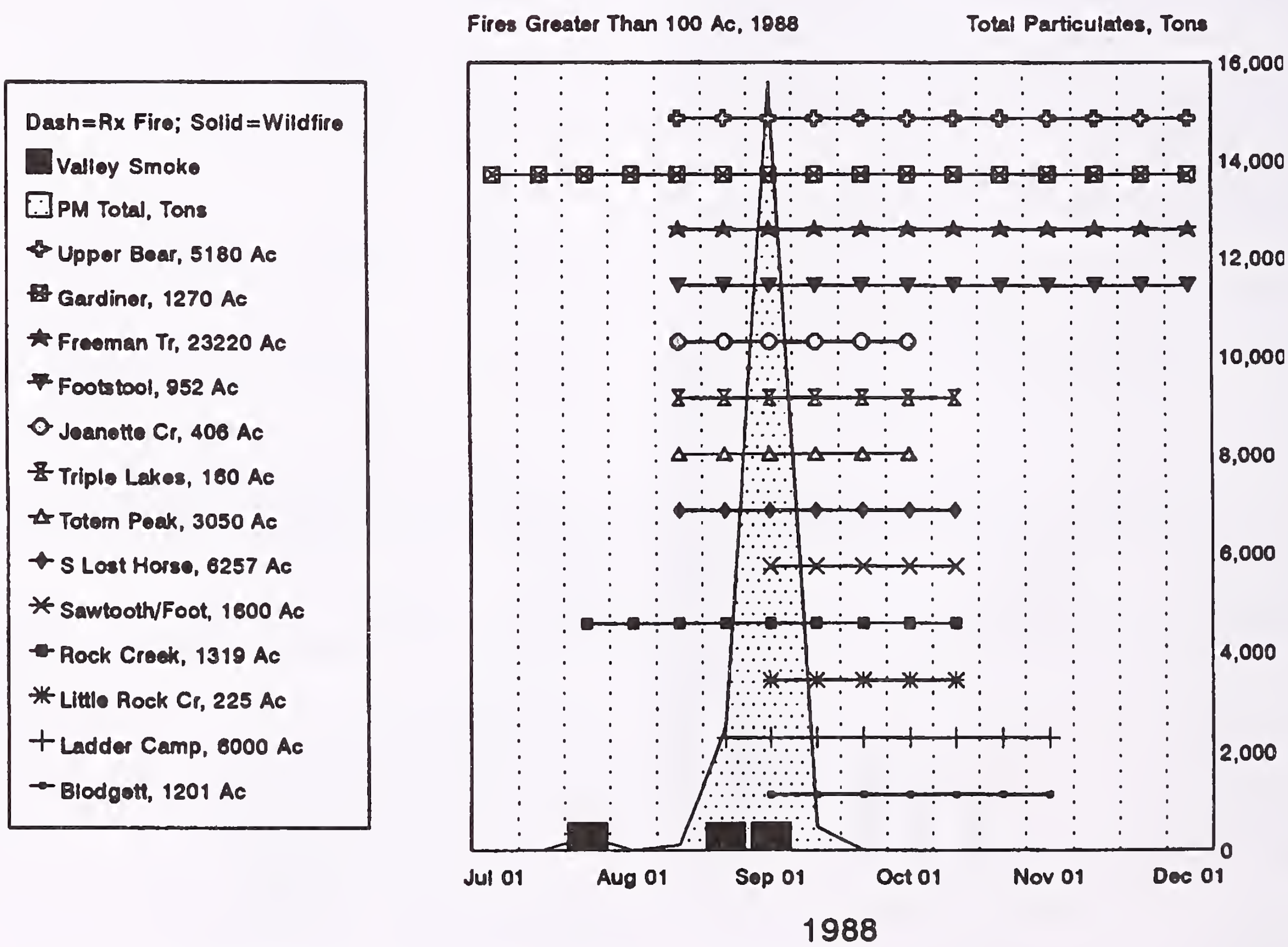




**Figure 3**—Seasonal distribution of total particulate matter from all fires and period of existence of fires greater than 100 acres for 1979 and 1988.

Table 5—Expected annual area burned (acres) for presettlement (P) fires and average annual area burned for recent (R) fires by fire severity and fire regime type

| Fire regime | Stand replacement P | Stand replacement R | Understory fire P | Understory fire R | All fire P | All fire R | P/R ratio |
|---|---|---|---|---|---|---|---|
| PP | 0 | 45 | 7,818 | 2,130 | 7,818 | 2,875 | 2.7 |
| SH | 417 | 186 | 0 | 144 | 417 | 330 | 1.3 |
| DF | 1,238 | 565 | 0 | 1,003 | 1,238 | 1,568 | .8 |
| WRC | 215 | 78 | 0 | 306 | 215 | 384 | .6 |
| LP | 6,024 | 3,539 | 2,276 | 1,084 | 8,300 | 4,623 | 1.8 |
| ES | 949 | 698 | 0 | 286 | 949 | 984 | 1.0 |
| WBP | 361 | 154 | 230 | 65 | 591 | 219 | 2.7 |
| AL | 576 | 424 | 0 | 162 | 576 | 586 | 1.0 |
| Rockland | 729 | 502 | 330 | 433 | 1,059 | 935 | 1.1 |
| Total | 10,509 | 6,891 | 10,654 | 5,613 | 21,163 | 12,504 | 1.7 |

The occurrence of presettlement understory fire was probably underestimated because trees with visible fire scars were not observed in some sample stands. But other studies (Arno 1976) have found that understory fire occurred widely in the lower elevation types, especially in the Douglas-fir type.

The difference between presettlement and recent fire activity was more than accounted for by the ponderosa pine and lodgepole pine types, which occupy 59 percent of the SBW. During the presettlement period, annual burned area for these two regime types was 9,162 acres greater than during the recent period, compared to a difference of 9,120 acres for all regime types (table 5).

Presettlement fuel consumption and emissions were 1.34 times greater than during the recent period. The difference between presettlement and recent periods was less for fuel consumption than for area burned. The main reason for this is that a greater proportion of presettlement fire was understory fire that resulted in less fuel consumption. Second, the presettlement fuel model for the ponderosa pine type contained less woody fuel to reflect the fuel reduction influence of frequent surface fire. Also, more fire during the recent period occurred in the western redcedar, Douglas-fir, and Engelmann spruce types, which had high fuel loadings and consumption rates.

## SUMMARY AND CONCLUSIONS

Presettlement area burned was 1.7 times greater than the recent period. A significant feature of the comparison is the substantially greater amount of understory fire that occurred during the presettlement period, especially in the ponderosa pine and lodgepole pine types. For all fire regime types, understory fire accounted for 50 percent of the area burned during presettlement and 45 percent during the recent period. The percentages are reversed for stand-replacement fire. Thus, the proportion of area burned by stand-replacement fire increased slightly from the presettlement period to the recent period.

The difference in area burned between presettlement and recent periods is probably due partly to the need to manage some fires as wildfires. Wildfires accounted for 56 percent of the area burned, although over 90 percent of this was managed under a confine and contain suppression strategy. Under this strategy, suppression action is limited to preventing fires from escaping boundaries and threatening property (Wakimoto 1989). But 69 percent of the fires less than 10 acres in size were managed as wildfires (table 2). Some of these may have become larger if they had been managed as prescribed natural fires.

An explanation for the small increase in proportion of stand-replacement fires during the recent period is speculative. Increased fuel loadings due to past fire protection, weather during fires, and greater suppression success on lower intensity wildfires could be factors.

Fuel consumption and smoke emissions were nearly one-third greater during the presettlement period. Analysis of valley smoke events indicates that they also occurred 1.3 times more frequently during presettlement. Averaged over all fire activity, visibility within the wilderness was estimated to be 20 to 30 percent less during presettlement (Brown and Bradshaw, in review). It is noteworthy that occurrence of extremely dense smoke that lasts for days has been reported by a number of early day writers (Bradshaw 1993). Thus, occasionally, presettlement smoke events were probably considerably worse than reported here.

Since 1960, smoke reported in the valleys lasted from 2 to 10 days during a given smoke event. Duration of smoke events was not significantly different between a period of full suppression and a period of prescribed natural fire management.

The prescribed natural fire program in the SBW has been one of the most successful programs in the United States for returning fire as a natural process. Nevertheless, this study showed that fire activity during the recent period was still less than that of the presettlement period, particularly for understory fire. This study may provide guidance to managers wishing to bring fire activity closer to that of the presettlement period.

How closely should the prescribed fire program match the fire regime characteristics of presettlement times? The answer depends on constraints imposed by the need to prevent unwanted fire and the variation in fire history that is acceptable for meeting natural-process goals. Exacting determinations of the variability in presettlement fire history will probably seldom be possible. Thus, deciding that a modern prescribed fire program departs significantly from presettlement fire regimes will require judgments based on incomplete knowledge. In the SBW, the difference in understory fire between presettlement and recent periods appears significant.

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# Prescribed Natural Fire Planning Considerations: Negotiating Conflicting Goals

**David L. Bunnell**

**Abstract**—The decision process involved in developing any plan to manage a prescribed natural fire must consider several divergent resource and management goals. In many cases, these fires may be projected to be, and eventually become, large and long-duration events. The exact final fire location, size, intensity, and timing of its movements will be largely uncertain. The fire will be largely defined by weather events. The uncertainty of these factors requires managers to closely consider the reality of their perceptions. In doing so, they must ultimately qualify and quantify resource objectives as input to the initial decisions involved in developing each individual fire plan.

The decision process used to develop any plan to manage a natural fire must consider the goals and objectives for wilderness, parks, and private lands, and all resource areas potentially affected. In examining land management goals and determining specific resource objectives, managers will consistently encounter differences of opinion, interpretation of laws or policy, and acceptable risk levels. During the planning process, it may become apparent that the uncertainties of the fire itself will be matched by the disparity of resource management needs and wants.

Prescribed natural fires (PNF's) are uncertain events. The definition of each fire will be largely determined by weather events that occur during the course of the fire. At the time each ignition is being evaluated, there is considerable uncertainty regarding the fire's spread rate and direction, timing of major fire movement, and fire intensity. These uncertainties, for an event that may be projected over an extended time period, relate specifically to risk elements associated with the PNF decision process.

## RISK CONSIDERATIONS

The element of risk will need close scrutinizing by all involved in the PNF decision process. Identification and acceptance of risk will be a key element in evaluation of all alternatives considered. Accepting that there is an element of risk in all decisions, the PNF decision may include substantial risk, both to potential resources affected and professionally for the decisionmaker.

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There are no known professional rewards for successful implementation of the PNF program. Results, however, indicate substantial ecological gain. Failure to implement the program may not result in any professional notoriety, but long-term consequences to the environment may be very negative in fire-dependent ecosystems. Escape or exceeding prescription parameters by individual PNF's carries a negative stigma for the decisionmaker and program. The results, however, have proven to be ecologically sound. Threats to and loss of private values outside the planned area continue to be the major consideration of risk evaluation.

As with all other elements and criteria of the PNF decision, risk elements vary substantially. Risk may be analyzed for many factors, such as:

- Risk to the wilderness/park user.
- Risk to the prescribed fire implementation team (actively monitoring fire).
- Risk to "resources"—air quality, cultural, capital improvements, etc.
- Risk to "resources" outside boundaries, including private lands.
- Risk of escape—economic, resource commitment for suppression, political, administrative.
- Potential and professional personal/program risks.

There are a lot of risk elements. Those listed represent some of the most common. The PNF decision can be very complex. Decisionmakers recognize a high risk level. That's why so few of them are making the PNF decision. Resource specialists and fire managers need to articulate and quantify relative risk levels before decisionmakers will feel more confident in accepting the risk of PNF decisions.

## PNF PLANNING AND NEGOTIATION

Part of this PNF "acceptance" trend will be how well the PNF plan is negotiated between functional areas and how well the plan substantiates or changes the decisionmaker's perceptions. We all have our personal and professional perceptions. The wilderness/park objective is all about perception. This interpretation of policy and law relates to individual and agency perceptions of the natural processes that shape and maintain the ecosystem. In this sense or this qualification of an objective, resources affected by the natural process of PNF require some quantification. Developing a process of defining the degree and amount of resource changes will allow us to successfully negotiate differences during very compressed time frames.

The planning process for PNF is constrained by stringent time factors. Under many successful program-level planning formats, the measure of time is hours, not weeks, months, or years, as is common in most other resource management decisions. The fire analysis must be done very quickly and efficiently to meet the time requirements imposed on each individual ignition under PNF consideration.

This process can be accomplished in several ways. It can be expertly accomplished in some situations by a single individual, small group, or full interdisciplinary team (IDT) of resource specialists. The IDT approach, which is utilized in most situations, generally offers the best analysis product (Tomascak 1991). It is in this format that the negotiation process is most beneficial to the PNF planning process.

As indicated, this becomes a rapid IDT exercise. The process includes valuing known and projected data while comparing judgments and perceptions. Initially, most proposals tend to lean toward functional direction and policy and individual resource considerations. The preliminary analysis and decision input tends to be highly qualitative. Progressions in planning and analysis require increasing quantitative determinations to serve as a solid basis for negotiation of divergent goals. It is through this valuation of resources that the PNF negotiation starts to define specific limits.

## DEFINING OBJECTIVES

Quantification of some resource values is difficult. The process for providing specific resource outputs or limitations and constraints may be the identification of the acceptable fire location and size, and possibly timing factors under which we will allow fire movement with or without interference. Resource considerations will vary for each PNF. Some common ones that may be defined during the negotiating process could be:

- Number of project dollars committed and available.
- Percentage of wilderness/park affected.
- Number of trails restricted or closed.
- Number of miles of trails restricted or closed.
- Number of administrative sites/capital improvements affected.
- Number of acres burned; number burned by various intensities.
- Number of days of visibility impairment from smoke.
- Percentage of outfitters camps or areas affected.
- Number of fires that can be physically managed by available resources.
- Number of access points affected.

At present, for most PNF's under Federal control, this process culminates in the negotiation of the maximum allowable perimeter (M.A.P.) for each fire. The M.A.P. negotiation is the one single element of the planning process that quantifies all the considerations negotiated during the PNF plan analysis. This "line-on-the-map" ultimately defines the total area that will be allowed to be treated by this fire. Analysis of this line will describe, quantitatively, many important resource elements. Some of the resources may be these specific acres, these trails, this bridge/cabin, this ridge, etc. The implementation narrative can and should contain specific implementation values and instructions that deal with all other plan requirements, including specific timing and resource commitments required in proposed holding plans.

## NEGOTIATION EXAMPLE

An example may be helpful in visualizing the tradeoffs between resources that may be negotiated during the PNF planning process. Figure 1 describes a PNF ignition site and several resource considerations an IDT will consider in the analysis of PNF feasibility. This figure provides the initial wilderness management-proposed M.A.P. as the wilderness boundary, the perception being that under the 1964 Wilderness Act, fire should be allowed to replicate the natural process of fire disturbance. On this basis, this is a feasible M.A.P. from a wilderness management viewpoint that could potentially impact all the specific resources annotated in this figure.

Figure 2 represents the initial fire management-proposed M.A.P. of controlling the fire at the the point of discovery. Fast initial attack by smokejumpers or by other suppression forces in remote areas generally reduces total fire expense and initial attack resource commitment. Recognizing that when fires are igniting in remote areas, the risk of fire in high-value resource areas is generally at high levels and initial attack resources may be at a premium. This is a potentially valid M.A.P. as well, from the traditional fire suppression perspective.

Figure 3 describes the recreation resource viewpoint. The area around the fire includes highly used mainline trails on both sides of the river, as well as an occupied outfitter camp. The IDT proposes the least disruption to a highly used area that is a destination area requiring several days to reach. Under these considerations, this appears to be a valid M.A.P. proposal as well.

In this example, the three figures represent a functional approach to developing the initial M.A.P. These proposals represent a rather radical resource philosophy, but in many cases, these may be the initial resource perceptions from these three functional levels. To simplify the process, the example will continue to expand on a potential negotiation in just these three primary resource areas while adding a fourth IDT member, representing the prescribed fire behavior analyst (PFBA).

The PFBA is charged with predicting the fire intensity, spread rate, and direction under expected average and severe-weather conditions. The PFBA works independently of other IDT members. The PFBA projections are displayed in figure 4. It should be noted that at this juncture the IDT members have made three widely divergent M.A.P. proposals. The PFBA severe-fire behavior prediction exceeds the proposed recreation M.A.P. and stays well within the extensive wilderness boundary. This data set projection becomes the first comparative basis for negotiation on this fire. The PFBA analysis produces a quantification of the fire in size and location over a specific timeframe without regard to specific resource perceptions or interpretations. These projections are based on a data set of high variability. The result should be tempered by experience and professional judgment, but

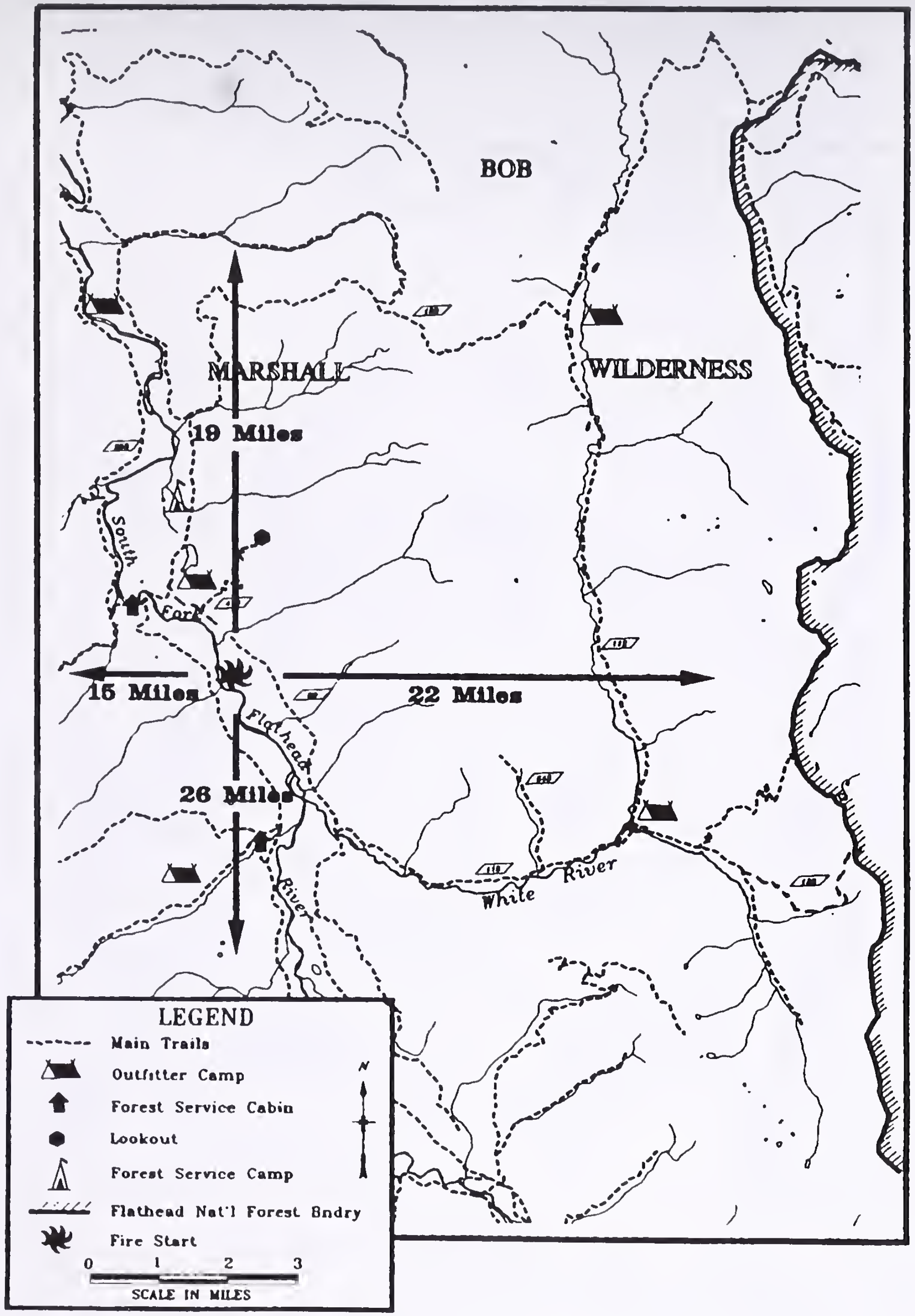


**Figure 1**—Proposed wilderness maximum allowable perimeter (M.A.P.) for a prescribed natural fire.

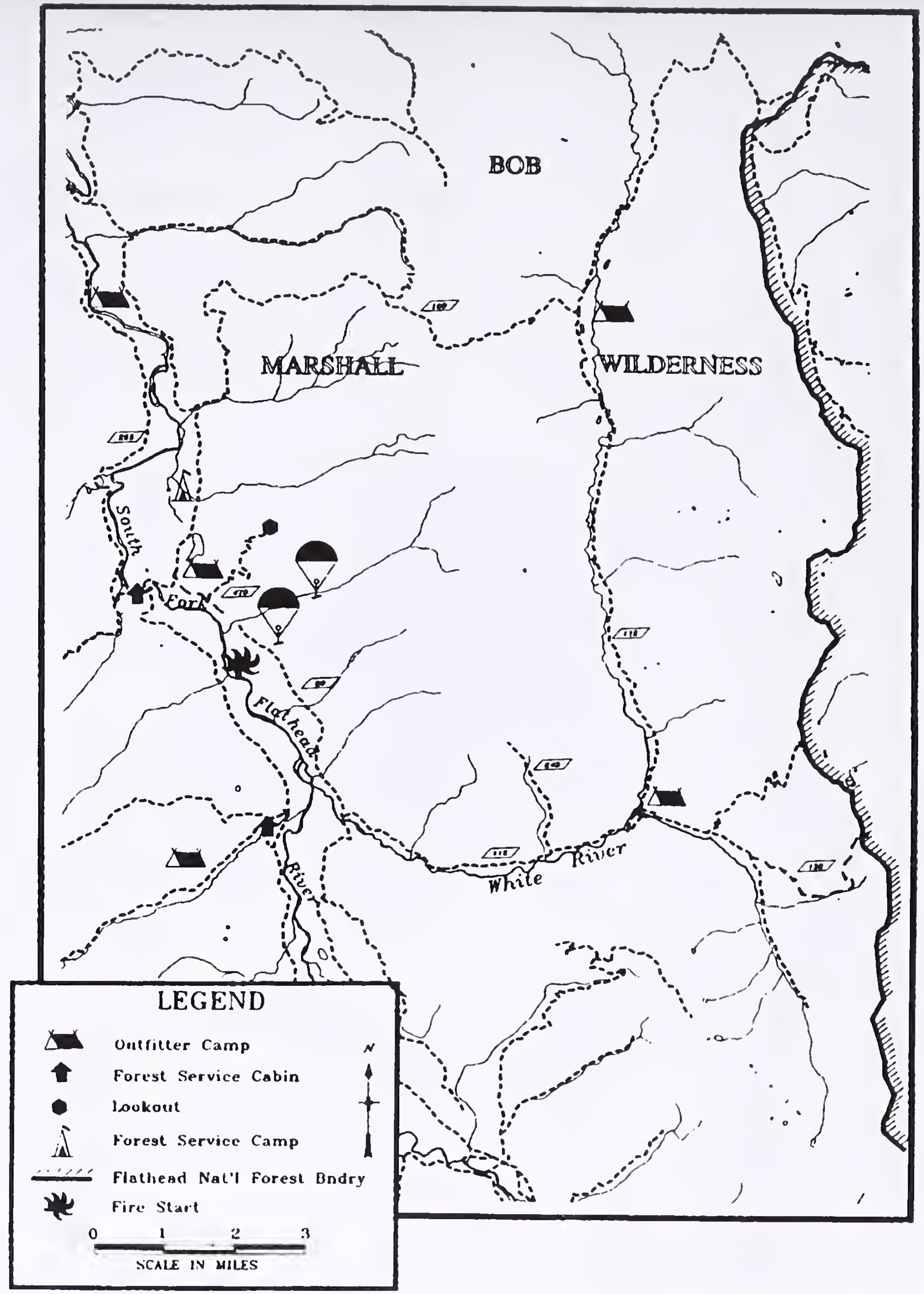


**Figure 2**—Proposed fire M.A.P. for initial control.

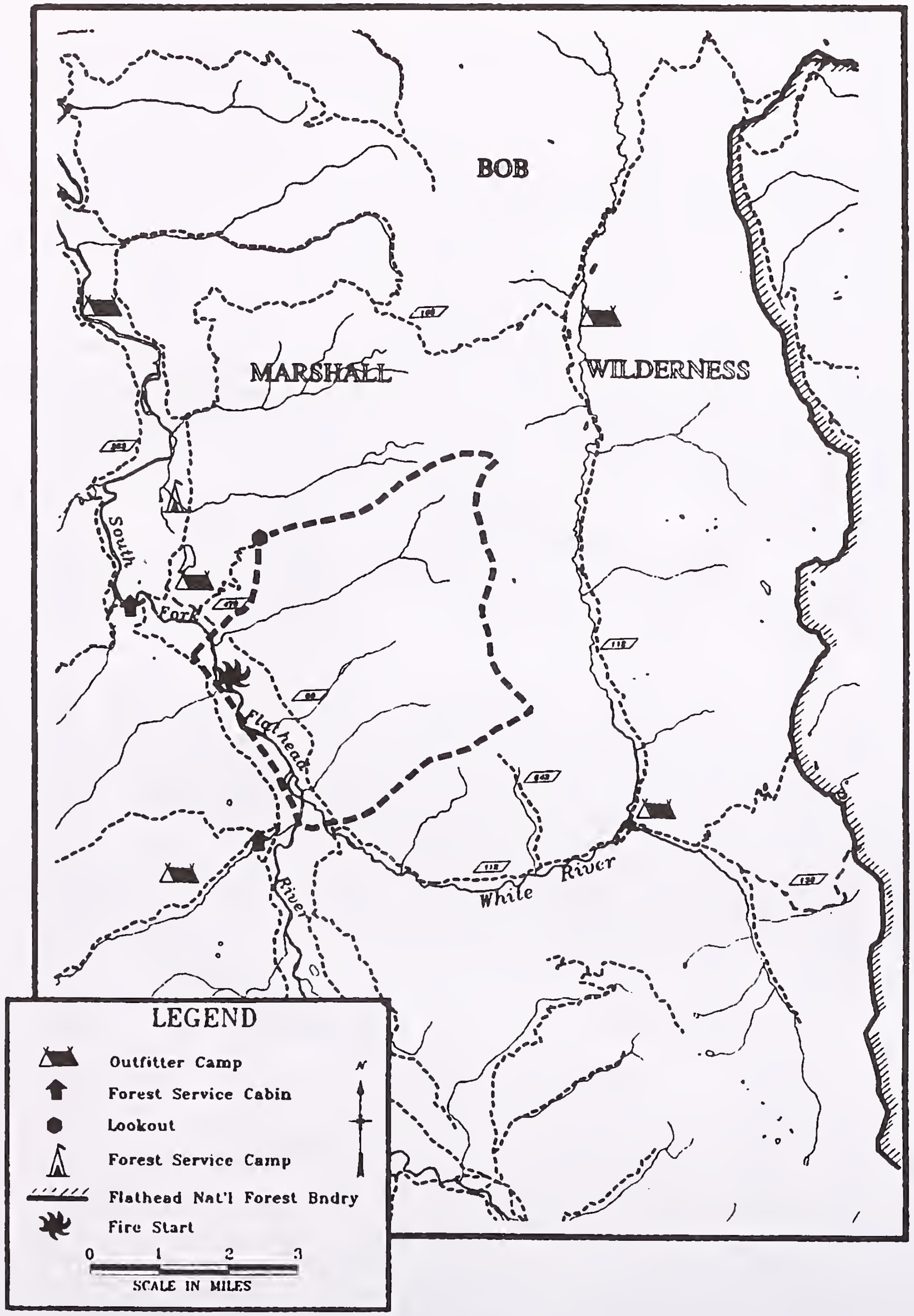


**Figure 3**—Proposed recreation M.A.P. featuring minimal description in a high-use area.

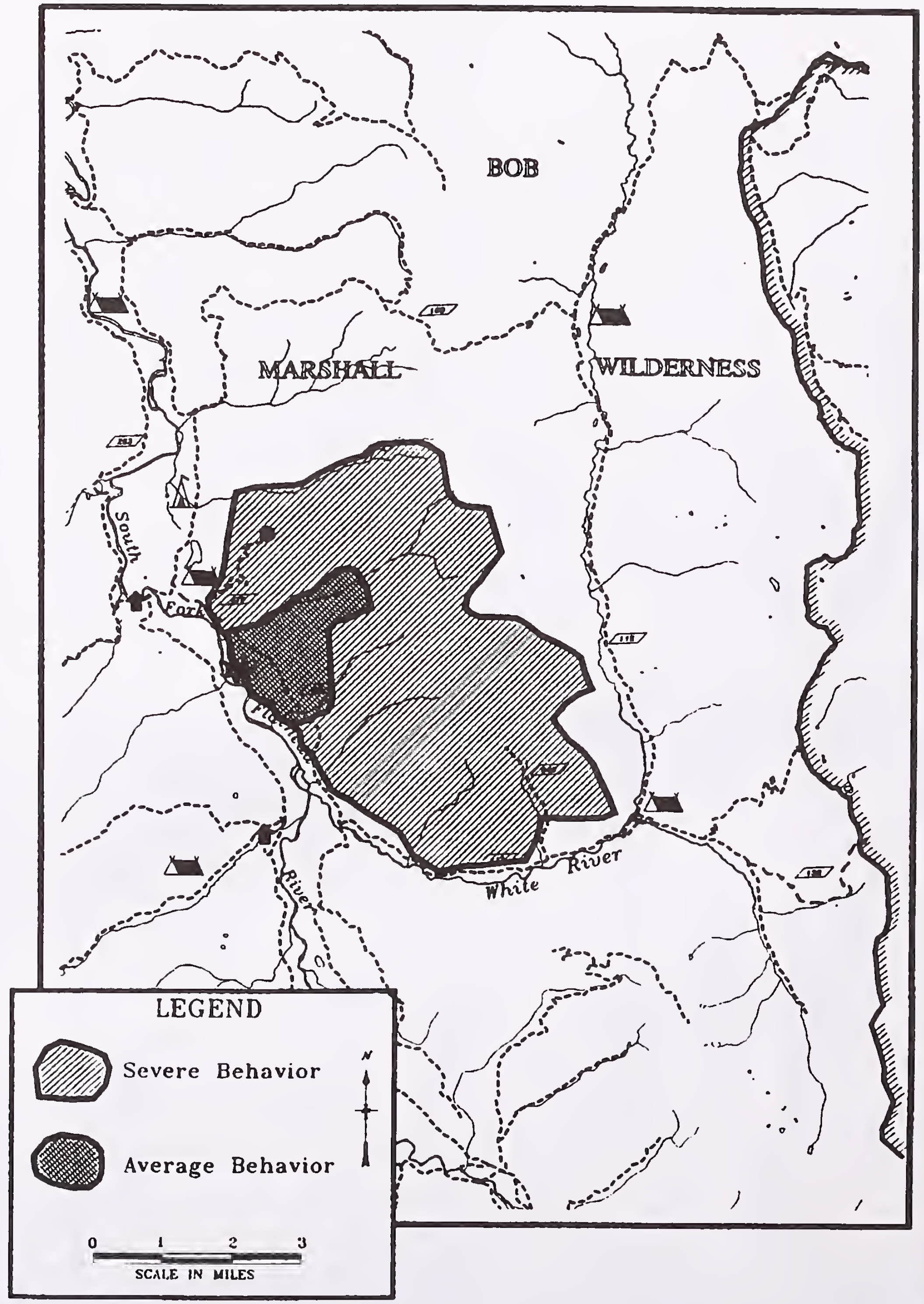


**Figure 4**—Fire behavior analyst projections.

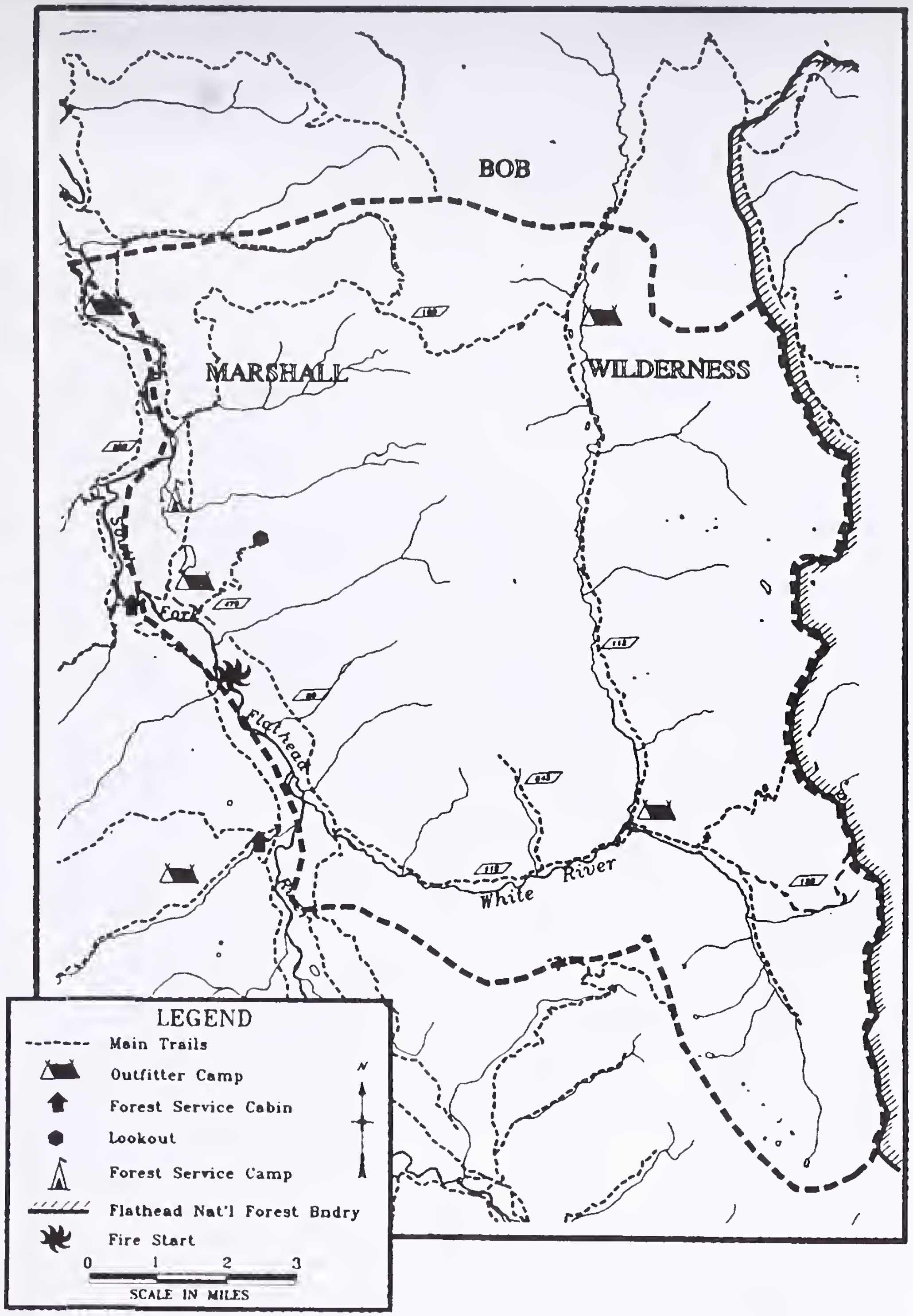


**Figure 5**—Proposed fire management M.A.P.

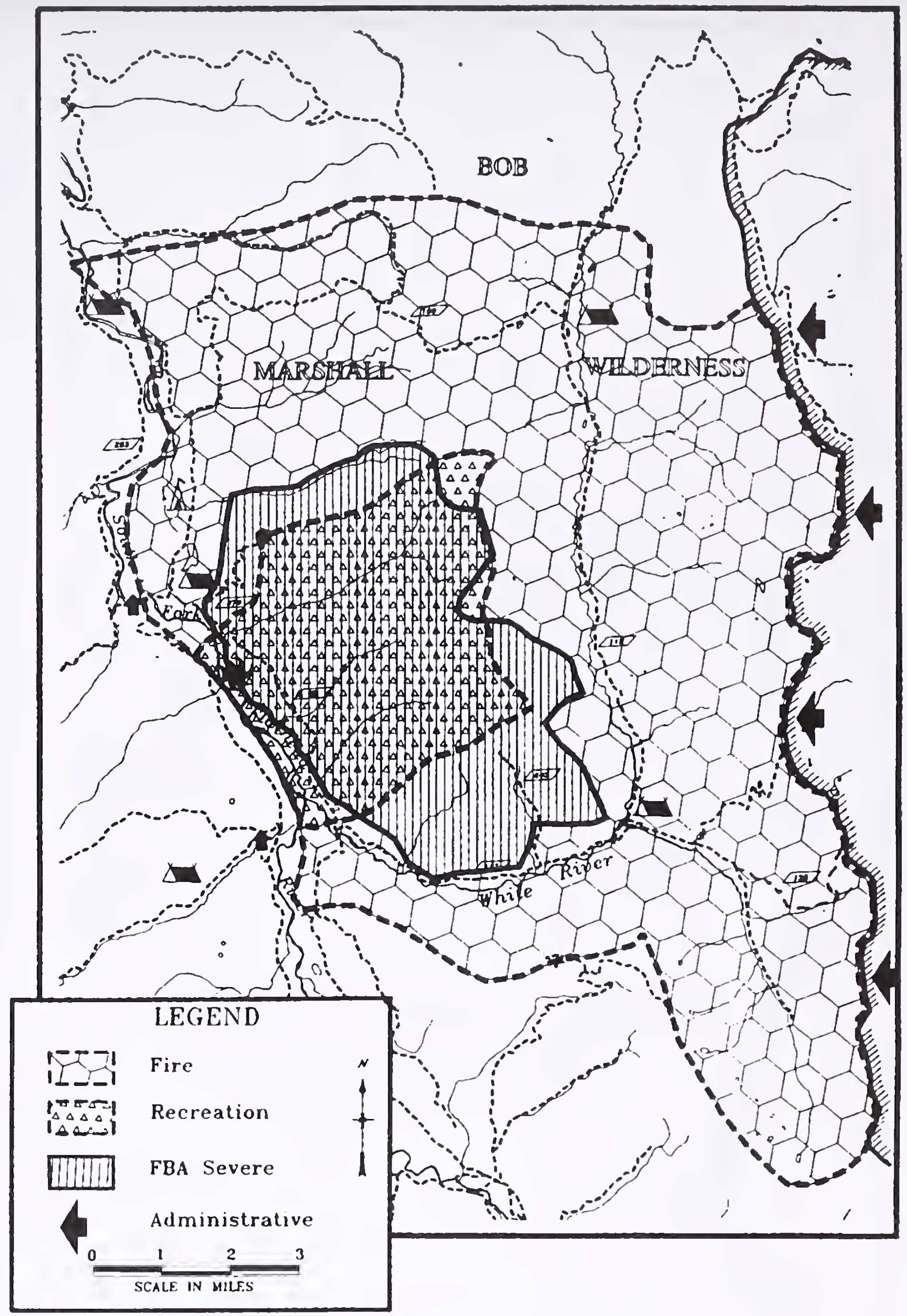


**Figure 6**—Initial M.A.P. proposals from fire management, recreation, and fire behavior specialists.

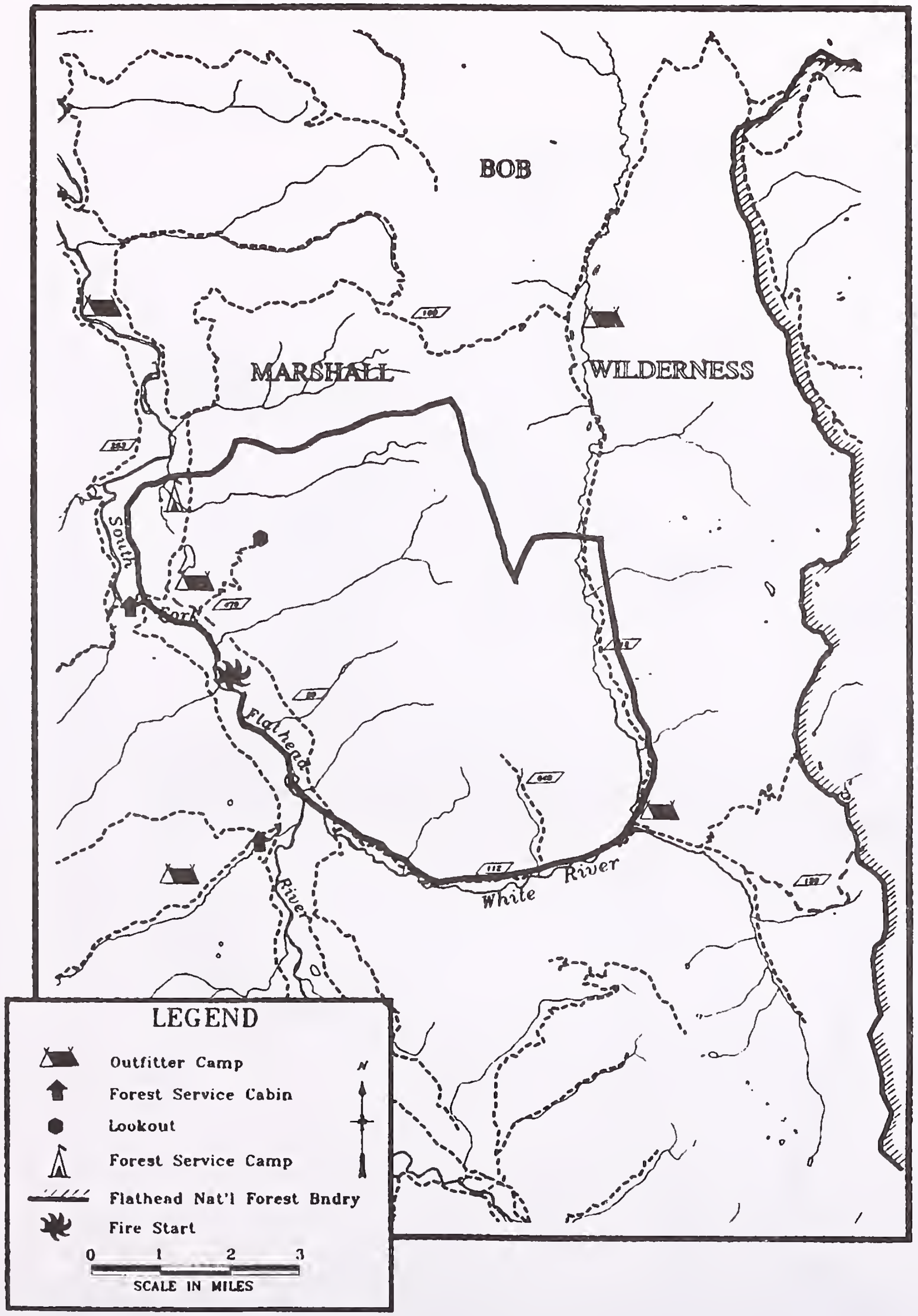


**Figure 7**—Recreation M.A.P. refined.

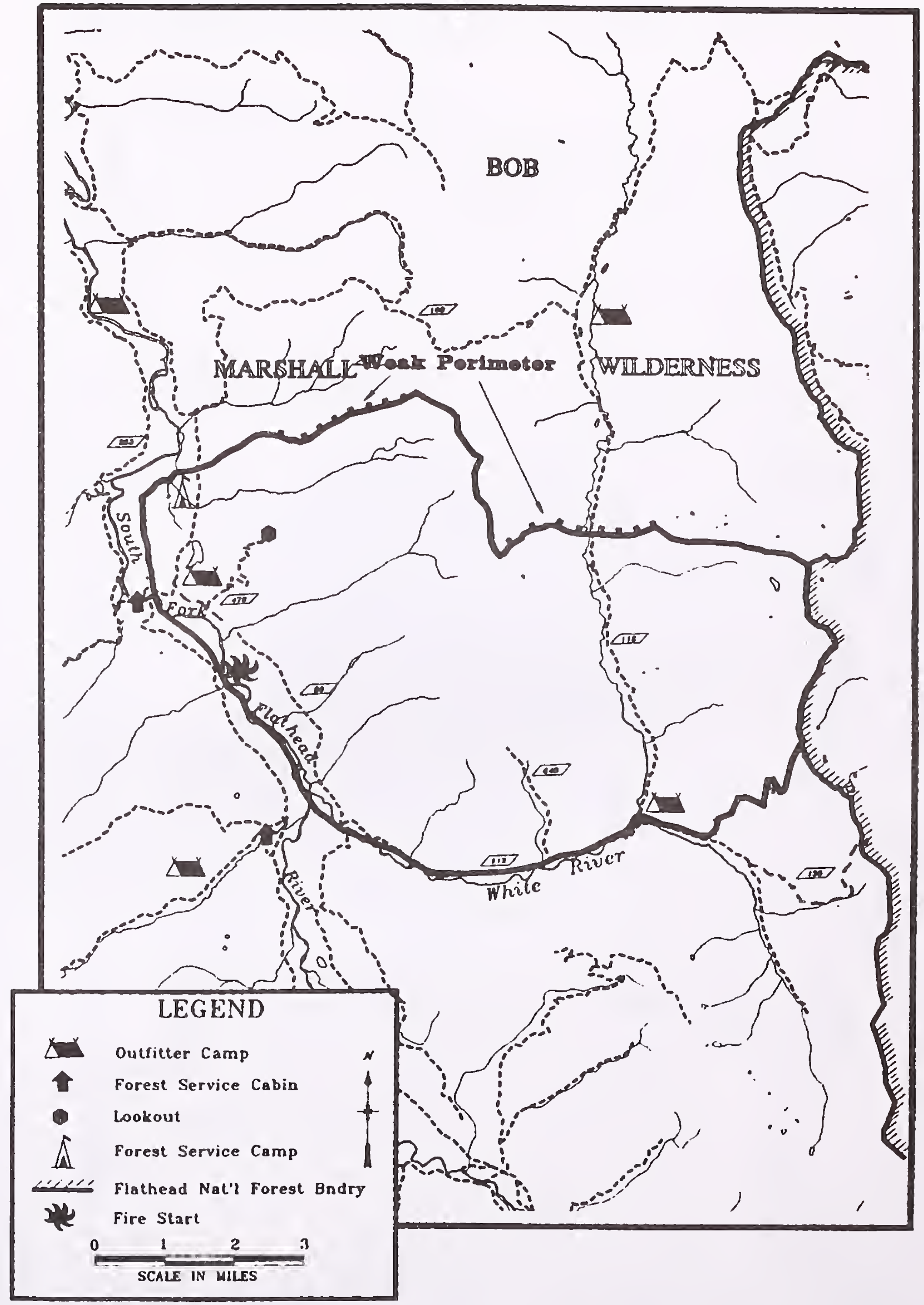


**Figure 8**—Fire M.A.P. accommodating same recreation resource considerations.

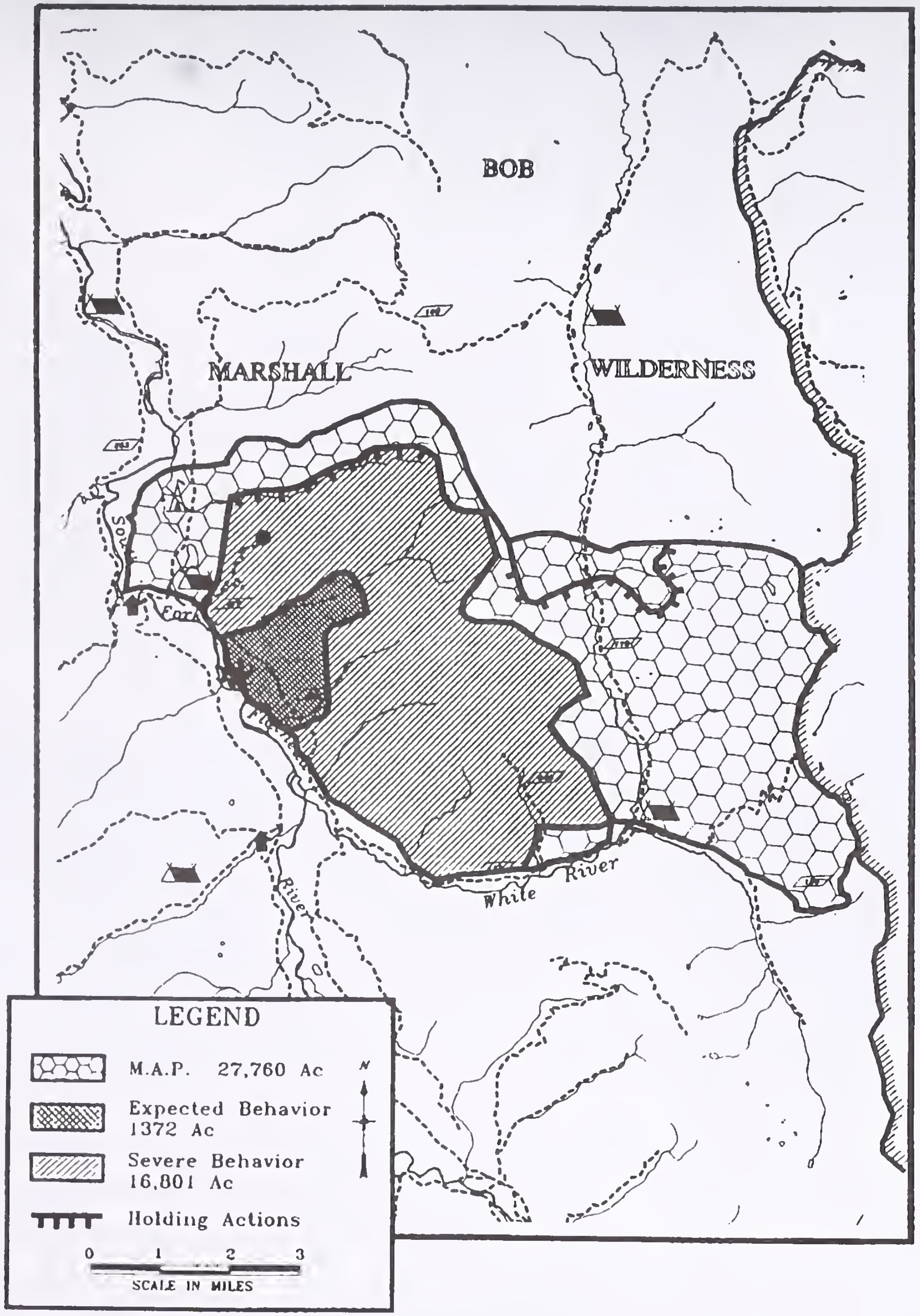


Figure 9—Final negotiated M.A.P.

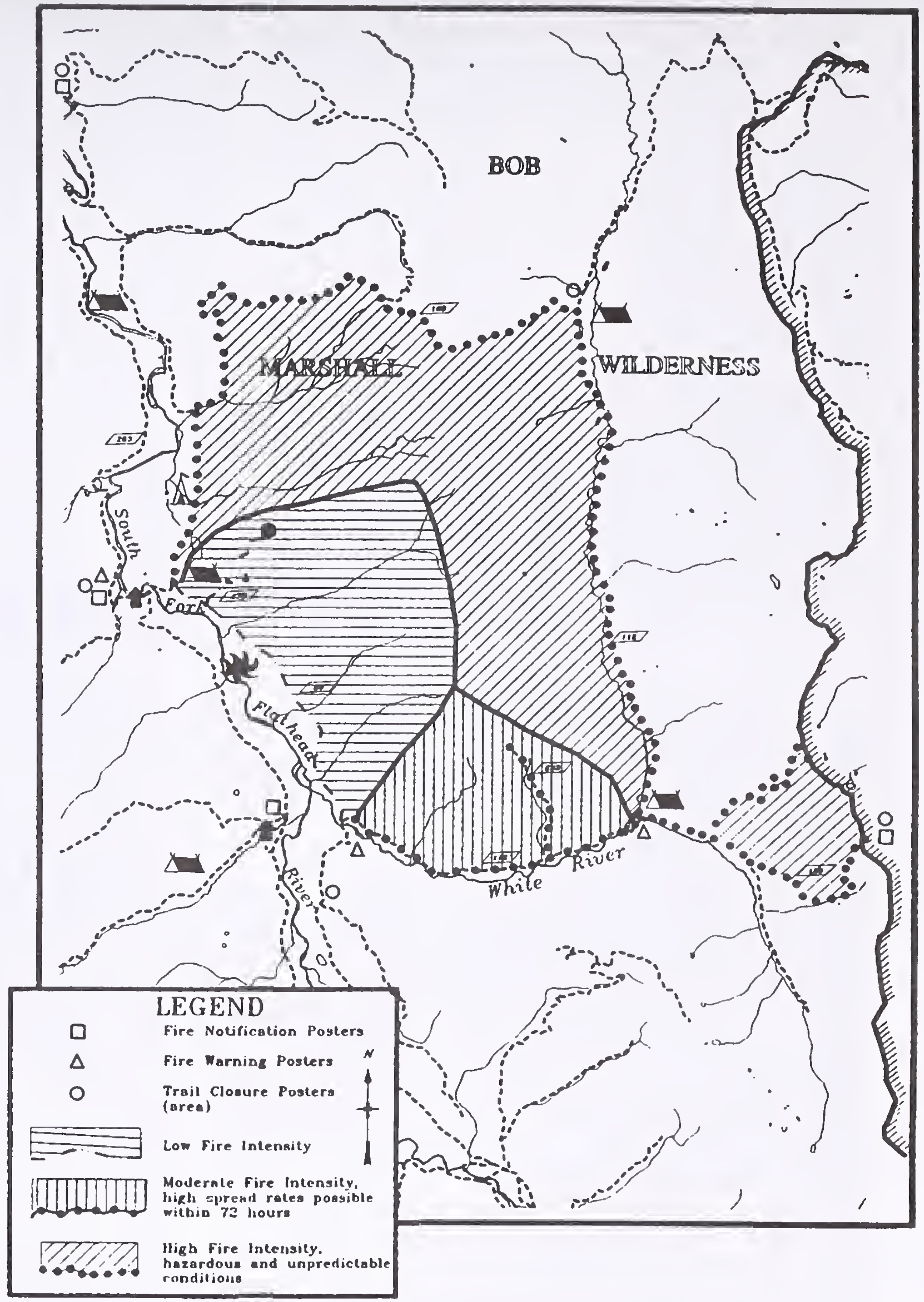


Figure 10—Public safety/management plan.

recognize and accept that these predictions will potentially lever all future negotiations.

Fire management considerations for a realistic M.A.P. determination are drawn to topographic and fuel continuity features that provide for a maximum level of fire defensibility. Taking advantage of exposed fuel-free ridges and available natural barriers, figure 5 is proposed as an M.A.P. that minimizes risk of escape from the boundary and presents a least-cost holding option while staying well outside the severe-fire projection area.

Figure 6 superimposes the initial M.A.P. proposals from fire management, fire behavior, and recreation specialists. Note that the severe-fire projection area exceeds the initial recreation proposals by a substantial amount in several areas.

Accepting an M.A.P. that is exceeded by the projected severe-fire behavior prediction may introduce a high risk factor. In this example, this risk factor is determined to be unacceptable to the IDT. On this basis, the IDT has a common goal and may now come together and start negotiating toward an integrated M.A.P. for this fire. The M.A.P. has been influenced by the fire behavior prediction and management direction regarding one of the risk elements.

Many of the concerns regarding this fire are recreation-use oriented. The proposal described in figure 7 results from an acceptance of the need for rerouting trail use, potential trail closures, defense of the lookout (which is listed as a cultural resource), potential movement of the Forest Service trail camp, and potential relocation of one outfitter base camp. The expense and logistics of actually implementing this proposal under various fire scenarios start to add a quantification to resource objective negotiations of how many, which ones, and why.

The proposed best fire-defensible M.A.P. encompasses too many other resource elements, particularly trail and outfitter camp locations. It is so far removed from the severe-fire projection that some of these other resource considerations take precedence. Figure 8 describes an adjusted M.A.P. that accommodates some of the recreation resource considerations. In developing this proposal, two major segments of the north flank are identified as presenting poor fire defense positions, which escalates a risk element and potentially increases fire defense costs. In this M.A.P. proposal, costs and resource commitments are calculated for potential holding actions. A feasibility analysis also starts to quantify potential costs and success ratios of needed actions on potential critical perimeter segments of identified weak segments of the north flank.

Figure 9 represents a final negotiated M.A.P. In this proposal, the line officer should be informed of all the tradeoffs negotiated between separate resource areas that went into the development of this line. From this disclosure and discussion, each resource specialist will have quantified their acceptance level of this fire and their potential to manage it within the provisions of the PNF plan. The line officer will be informed in detail of the specifics addressed by the team and will have a visual display that shows what specific area and which specific resource elements will be affected by this natural event.

This final proposal describes a M.A.P. that may affect five trails, a Forest Service trail camp, two outfitter base camps, a lookout of cultural value, two river float campsites, and 27,760 acres in total vegetative change. Additionally, two significant perimeter segments are identified that will require fire manipulation by holding resources prior to the fire approaching these locations. A public safety plan is developed (see fig. 10) and a holding plan is constructed that specifies which resources will be employed to mitigate fire movement in critically described areas of the north flank.

## SUMMARY

Negotiating the PNF plan requires tradeoffs that potentially affect resource objectives between functions. The risks associated with these negotiations need to be articulated to test their relative values. Risk elements must be identified and quantified, at least in a relative sense, and described to the decisionmaker in a clear fashion. In doing so, we will collectively start to set aside selfish and singular resource goals and objectives in developing more integrated PNF plans.

Philosophical objectives of allowing any fire to accomplish its natural role in land management must be evaluated against other and against better defined and measurable goals and objectives. The development of the M.A.P. can include the integration of negotiations that define the parameters of acceptability for each PNF. The PNF plan describes what is acceptable and what is not for each individual fire. This plan specifically describes actions we are prepared to take in allowing this fire to assume its natural role in the environment. It also describes what management constraints we place on this fire event. Through this process, resource objectives are defined and quantified for each PNF occurrence.

The most primary of wilderness and park objectives is the maintenance of the "natural process." In the large wilderness areas of the West, these lands were born from and textured by periodic fire. To increase the success of this program, we need to set aside our narrow short-term needs and expectations for the benefit of long-term larger objectives. We must allow this element of the natural process to continue by recognizing and accepting the risks to our human values.

The prescribed natural fire concept is based on and supported by science. Every day that we attempt to stall or subvert this natural process brings us a day closer to losing this management option. We have demonstrated our professional expertise in identifying what needs to be accomplished and how to do it.

Ultimately, the decisionmaker must say yes or no. An integrated negotiation of each significant resource goal that results in the quantification of resource values will allow each decision to be reasoned and made with confidence.

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# Constraints and Solutions

## Panels



# Fire Issues and Communication by the Media


## Conrad Smith



**Abstract**—Examination of 320 stories about wildfire published since 1988 suggests that journalists did not learn from the mistakes they made reporting the Yellowstone fires. The conventions of journalism, which value drama over explanation, suggest that wildfires and other natural catastrophes will often be reported in apocalyptic terms rather than as the predictable outcomes of natural force . Studies of how journalists reported five major stories suggest five factors that determine how wildfires are reported: (1) source enterprise, (2) cultural resonance, (3) issue salience, (4) newness, and (5) the degree to which the setting is rural or urban. Because of these criteria, news organizations sometimes do a poor job of providing the kinds of information needed by news consumers to reach intelligent conclusions about how public lands should be managed.


After the 1988 Yellowstone fires, I looked at nearly 1,000 news accounts to find out how journalists report wildfire (Smith 1992). Many of you in this room helped by evaluating the accuracy and completeness of the network television stories. Today I will review what I found out about the 1988 fires, tell you what I learned about wildfire coverage since 1988, and offer a conceptual explanation of why reporters often misunderstand wildfire.

## YELLOWSTONE FIRES COVERAGE

Some of the 1988 reporting from Yellowstone was thoughtful and accurate, especially after mid-September when the fires were under control. But the impression created by the television networks and the majority of urban newspapers, especially while the fires were a major news event, was that Yellowstone had been pretty much destroyed and that prescribed natural fire policy was the reason. Yellowstone-area newspapers and the Los Angeles Times did a more balanced job of reporting than many other news organizations.

Stories often fanned controversy about prescribed natural fire policy without explaining in any detail how it was administered, where it came from, or why it was established. Only one of 936 stories mentioned the 1963 Leopold report that forms the philosophical foundation of National Park Service wildfire policy (Matthiessen 1988). Major news organizations such as the New York Times and the three television networks said authorities were allowing Yellowstone-area fires to burn more than a month after they had been declared wildfires and were subject to suppression. These mistakes were never corrected.

In hindsight, many reporters felt the media did a poor job reporting the Yellowstone fires. Each of the three network correspondents who did the most stories from Yellowstone, for example, conceded afterwards that coverage was exaggerated. Major news organizations did penance by returning the next spring to write about the "rebirth" of the park. T. R. Reid, who reported the fires for the Washington Post in 1988, later asked in an opinion piece (Reid 1989) "whether we reporters learned anything from our blunders in 1988."

## WILDFIRE COVERAGE AFTER 1988

I attempted to answer Reid's question about whether journalists learned from their 1988 mistakes by looking at elite press articles about wildfire in national parks and national forests that were published during 1989, 1990, 1991, and 1992. The analysis is based on 320 stories that appeared in the New York Times, Washington Post, and Los Angeles Times, located through Boolean logic searches of the full texts of each newspaper in the NEXIS computer database. My conclusion is that the media establishment did not learn from its 1988 mistakes.

Consider how reporters for the three prestigious newspapers used language in stories about wildfire in 1988 and afterwards. In 1988 reports of the Yellowstone fires, the phrase "let it burn" appeared 86 times, "natural burn" 10, and "prescribed natural fire" five. In 320 wildfire stories published after 1988, the term "natural burn" appeared twice. The phrase "prescribed natural fire" occurred three times, all in 1989 Washington Post stories written by T. R. Reid. In the same post-1988 stories, "destroy" appeared 368 times, "evacuate" 317, and "battle" 188. The fires "devastated" 83 times, "ravaged" 35 times, and created "victims" 56 times.

Wildfire stories in 1988 often talked of the number of acres (not trees) "destroyed". After 1988, readers of the Los Angeles Times learned that 15,000 acres of Yosemite had been "destroyed" by wildfires (Hubler and Miller 1990), and 22,000 acres of the park had been "devoured" (Roderick and Sahagun 1990b). In other post-Yellowstone stories, readers learned that wildfires "burn over," "char," "grow ferociously," "rage untamed," "roar down canyons," "close freeways," "race through affluent suburbs," "invade posh residential communities," "engulf," and "consume homes," "raze residences," "leapfrog from house to house," "storm through homes," "hopscotch destructively across southern California;" "erupted," "scorched," "threatened," "swept," "whipped through treetops like blast furnaces;"


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"blackened" and "consumed" acres, "hurtled out of the hills," "ate 212 houses," and "roamed like random killers."

The anthropomorphic interest in animals that characterized 1988 coverage did not change in subsequent years. In 1988 stories about the Yellowstone fires, there were 71 mentions of elk, 21 of bison, 15 of deer, nine of buffalo, five of sheep and four of Bambi. In post-1988 wildfire stories, elk were mentioned 53 times, bison 31, grizzlies 21, and squirrels twice. The effort to dramatize and humanize coverage can be seen, for example, in a Los Angeles Times report (Roderick and Sahagun 1990a) about a pack of 30 food-stressed squirrels that allegedly hounded tourists at Glacier Point in Yosemite after 1990 wildfires there temporarily deprived park animals of "picnic leftovers and junk food handouts."

The Intermountain Fire Sciences Laboratory in Missoula, described twice in stories about the Yellowstone fires (Malcolm 1988; Maugh 1988), was not mentioned in any of 320 post-1988 stories. Wildfire coverage after 1988 was typified by a July 10, 1989, Washington Post headline (A5): "Wildfires Rage in West." Most stories in 1988 and in subsequent years focused on what burned, what was threatened, and who was responsible; not on the biological or policy context in which wildfires burned.

## CONCEPTUAL EXPLANATION

After examining how journalists reported the Yellowstone fires and four other events that received extensive media attention, I discovered common themes that offer a tentative conceptual explanation of the professional values that determine how wildfires and other events are covered. The analysis is based on reports of the Yellowstone fires (Smith 1992), the Exxon Valdez oil spill (Smith 1992), the Loma Prieta earthquake (Smith 1992), Iben Browning's unscientific projection that an earthquake would strike New Madrid, MO, about December 3, 1990 (Smith 1993); and coverage of the growth-regulating chemical Alar used on apples, which caused a national scare in 1989 (Smith 1994).

In each of these major news events, the amount and kind of reporting appears to have been a function of five factors: (1) source enterprise, (2) cultural resonance, (3) issue salience, (4) newness, and (5) the degree to which the setting was rural or urban. I will attempt to explain by discussing each of the factors in more detail.

### Source Enterprise

One of the traditions of journalism is that reporters attribute information to named sources. As Gans (1980) noted, news is weighted toward sources eager to be heard. Molotch and Lester (1974, 1975) described news coverage as a battle among sources with vested interests to define events in self-serving ways. Entman (1989) suggested that journalistic practices make it so easy to manipulate news that public officials who talk honestly with reporters do so at their peril.

The "source enterprise" factor describes the degree to which news sources successfully court media attention. Success is measured by the degree to which resulting stories legitimize the source-generated viewpoints and news angles. A fire ecologist who sought media attention would rate high on source enterprise if the resulting story focused on the biological role of wildfire. A politician who sought media attention to portray wildfire as an economic disaster would display high source enterprise if the resulting news account took that perspective.

In the Exxon Valdez oil spill, the State of Alaska, which received much of its revenue from oil and which had approved the ineffective oil spill contingency plan, launched a full-scale propaganda effort to portray itself as the innocent victim of an inept oil company. President George Bush, who had diverted Coast Guard funding from maritime safety to drug interception and thus reduced safety precautions in Prince William Sound, dispatched cabinet officials and high-ranking Coast Guard officers to assure the public that the government was responding in appropriate ways.

Dennis Kelso of the Alaska Department of Environmental Conservation and Coast Guard Commandant Paul Yost proved adept in offering reporters sound bites that made good copy and obscured the culpability of each government body. The most-quoted Exxon official, Frank Iarossi, was in Alaska primarily to deal with the technical problems of salvaging oil. He proved less skilled in dealing with reporters, exacerbating Exxon's public relations problems. Alaska and the Bush administration emerged relatively unscathed.

After the Loma Prieta earthquake, United States Geological Survey (USGS) geologists, who had been courting reporters for 25 years (Wallace 1990), rated news coverage much more accurate and complete than seismic engineers, who had not sought media attention in an organized way. The California Department of Transportation (Caltrans) made all its records and many of its people available to reporters, thus defusing early media suggestions that Caltrans negligence was responsible for the freeway collapse that was responsible for most of the earthquake-caused deaths.

Although Iben Browning had no standing as a seismologist and only one supporter among academic seismologists, his unscientific earth quake prediction was often reported as scientifically credible until the USGS released a report by a committee of 11 respected scientists that discredited Browning's prediction. Regression analysis indicated that this source enterprise by the USGS was the single largest factor explaining the variance in the accuracy of news accounts about Browning's prediction (Smith 1993a).

The alleged relationship between apples treated with the growth regulator Alar and cancer received little media attention until a public relations firm hired by the Natural Resources Defense Council (NRDC), an environmental advocacy group, exercised source enterprise by arranging an exclusive report on the CBS program "60 Minutes." After that report spawned hundreds of others, sales of the chemical were banned in the United States on the basis of controversial evidence that had been available long before the "60 Minutes" program.

In coverage of the Yellowstone fires, Federal agencies were relatively unsuccessful in their attempts to influence reporters in ways that focused attention on the natural role of fire in forest ecosystems. In part, this reflected poor coordination between three separate information

efforts: those representing the forest and park services, and those representing the individual fire complexes. The information effort lost credibility among some reporters because some fire information officers did not know very much about wildfire and did not understand media practices. Yellowstone-area politicians and their constituents were more successful in generating news accounts that focused on the commercial impact of the fires.

## Cultural Resonance

If the message offered by news sources resonates with widely accepted cultural values (for example, Bambi terrorized by fire; Smokey Bear's admonitions that fire is bad), it will take less enterprise to influence reporters than if the perspective offered by sources goes contrary to popular wisdom.

Because journalists hold oil companies in low esteem (Meyer, 234, 235), and because the drunken sailor is a part of maritime myth, the perspectives that alcohol caused the wreck and that Exxon was responsible for failed efforts to contain the spilled oil resonated with cultural values. Other causes identified by the National Traffic Safety Board, such as poor Coast Guard oversight, resonated less with popular conceptions and received less media attention, independent of efforts by news sources to influence coverage. Because Alaska symbolized uncorrupted wilderness for many Americans (Nash 1982), the idea that the State bore no responsibility for the spill or unsuccessful cleanup efforts resonated with popular wisdom. For that reason, the State could get favorable coverage with considerably less enterprise than Exxon.

Most of the damage from the Loma Prieta earthquake occurred outside San Francisco in places such as Oakland, Santa Cruz, and Watsonville. But San Francisco is better known than the other cities, and the 1906 earthquake there is part of our cultural lore. Because San Francisco is a familiar reference and resonates with our knowledge of earthquakes, the media focused on San Francisco far more often than the distribution of seismological effects would have suggested.

Iben Browning's earthquake prediction resonated with the cultural myth that earthquakes can be predicted by observing animal behavior and through other simple means. Perhaps for that reason, inaccurate reports that Browning had earlier predicted the Loma Prieta earthquake and the eruption of Mount St. Helens were initially described by journalists as fact without being investigated.

The idea that apples grown with Alar might poison us resonated with widespread fears that artificial chemicals used to grow food are one of the greatest threats to the public health. Because of these fears, it was relatively easy for the NRDC to focus media attention on the chemical. The Alar-treated apples perhaps reminded us of the poisoned apple in Snow White. Because of these cultural resonances, it would have taken considerably more source enterprise to persuade journalists that pesticides and other chemicals used to grow food pose a relatively small health risk, independent of which perspective is more accurate.

Because we are culturally conditioned to think of fire as destructive, it will take no source enterprise to persuade journalists to portray wildfire negatively. In face of this widespread conception, source enterprise, however skilled, may not be enough to persuade reporters to pay much attention to wildfire as a biological process.

## Issue Salience

The salience of an issue or event—the degree to which it captures our attention—is another factor that appears to influence how events are reported. Thus wildfires in Yellowstone National Park, which is widely known, received considerably more media attention than equally intense fires in lesser known areas such as the Scapegoat Wilderness between Missoula and Great Falls, MT.

The highest salience issue of the five I examined was possible mortality from Alar-treated apples. Because nearly everyone eats apples, most of us were potentially at risk. The two earthquake stories probably ranked next. Because most of us drive over bridges and on freeways, we could relate personally to stories about how those structures collapsed and killed people. Iben Browning's dubious prediction—a 50-50 chance of a major earthquake near New Madrid, MO, within two days of December 3, 1990—had greater specificity than USGS predictions that estimated the probability of a Bay-area earthquake over a period of three decades. It was therefore more journalistically salient and received greater coverage.

The Alaska oil spill and Yellowstone wildfires were salient in symbolic ways. Each symbolized the corruption of innocence by outside forces. Alaska, the pristine last frontier, and Yellowstone, the Crown Jewel of the National Park System, were portrayed as innocent victims of bad management by inept administrators. In Alaska, journalists increased issue salience by portraying environmental damage in terms of doomed sea otters instead of explaining that the real threat was that mortality among less charismatic species in some parts of a complex aquatic ecosystem might eventually affect other parts of that system. In Yellowstone, issue salience was greater because journalists focused on national icons presumably threatened (for example, Old Faithful Geyser) and presumably terrorized wildlife rather than immense stands of lodgepole pine.

Wildfire ecology probably has considerably less salience than threatened national icons and allegedly inept land managers, and is therefore much less likely to be the focus of stories about wildfire.

## Newness

News is, by definition, not about what is old. Because I knew I would be making this presentation, I brought an example from my hometown newspaper. First, I bring your attention to a story at the top of the front page, which was then quite new (Knight-Ridder Tribune 1992). The headline says "Clinton, Bush meeting terrific." Then I'd like to read a headline in the second section. It says "Time is short to save the earth, scientists warn" (Lafferty 1992). The less-prominent story describes a warning about pollution and overpopulation signed by 98 Nobel Prize winners and 1,458 other scientists. Because most of the information had been available for some time, the second story was less newsworthy.

Where a wildfire has burned since yesterday, who or what is now most at threat, and the most recent administrative actions will always be newer than ecological issues, and therefore more newsworthy. In Alaska, stories about today's events (sea otters rescued, beaches cleaned) and symbols (oiled shorelines and wildlife) were always more newsworthy than information that would help prevent future spills. In California, stories about damage and victims were always more newsworthy than information about past zoning decisions and funding cutbacks that assured widespread damage to buildings and roads. Stories about Iben Browning's earthquake prediction focused on public reactions to it rather than its scientific merit. Many stories about Alar and apples described the allegations about the carcinogenic nature of the chemical, but only a few investigated the merit of those charges.

## The Urban Rube

Most of journalism is practiced in urban areas. In 1988, I would have said wildfires burn in rural places, though events in the Berkeley Hills, Santa Barbara, and Spokane temper that observation. Urban reporters are generally better qualified to report urban than rural phenomena, and generally more interested in urban events. Urban crime, politics, and scandal are appropriate staples of news, because cities are where most of us live.

We've all heard stories about the country rube who goes to the big city and gets taken because he doesn't know the ways of the city. "You can take the boy out of the country," etc. But the same concept works in reverse when urban journalists report rural events. A reporter who is quite sophisticated about the subtleties of Washington politics may be completely out of his element in a story about Federal lands in rural areas. Thus Bill Greenwood, Washington correspondent for ABC, reported in 1988 "there's no doubt the flames (in Yellowstone) will cost the timber industry tens of millions of dollars" (World News Sunday, September 18).

In Valdez, AK, reporters from prestigious national news organizations generally knew much less about the background and issues relevant to the Exxon Valdez oil spill than their counterparts from Alaska-based news organizations. In California, Bay Area reporters generally had lived through other earthquakes, and many had working relationships with USGS scientists in Menlo Park. Reporters who flew to San Francisco from other urban areas had fewer bearings and were more likely to buy into the myth that earthquakes are somehow more dangerous than other natural disasters, such as the hurricanes that sweep through the southeast every few years.

The New Madrid fault, which traverses a predominantly rural area, was the focus in 1990 of stereotypical stories about simple folks in small-town America and their fears about the great earthquake. In Alaska, stories about the Exxon Valdez oil spill perpetuated myths about the primitive lifestyles of native peoples, portraying them as less assimilated into the cultural mainstream than they really are. In Yellowstone, many reporters used urban concepts to explain rural fires. If the fires were still burning, the thinking went, somebody must have screwed up. By the same logic that fires can destroy buildings, they can destroy rural landscapes.

## CONCLUSIONS

For a number of reasons, wildfires are more likely to be covered as disasters than natural processes. The specious logic that fire is always bad and extinguishing it always good will probably continue to determine how most wildfires are reported. Federal land managers and fire scientists can change this to some degree by working actively to establish long-term working relationships with journalists. Managers and scientists will have less success changing the journalistic importance of cultural resonance, issue salience, and newness. They can influence reporters for major urban news organizations only to the degree they have access to these reporters.

The 1988 Yellowstone fires, which focused massive media attention on prescribed natural fire policy and resulted in a few stories about the related scientific issues, helped legitimize fire ecology as an occasional news topic. Yellowstone was probably the best opportunity in decades to educate journalists about the scientific aspects of wildfire. Because many reporters now share that reference, it may be easier in the future to get their attention. Managers and scientists who assertively, thoughtfully, and persistently seek out media contacts are the most likely to influence the manner in which journalists report wildfire. Those who delegate these jobs to public information specialists will have a smaller chance of success.

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# Fire in Wilderness and Parks: Political Issues

**Elmer J. Hurd, Jr.**

**Abstract**—Resource management plans and objectives may be sound ecologically and within agency mandates for management, but impossible to expedite because of political considerations and obstacles. It is imperative that these be recognized in the planning processes and confronted professionally by the agency managers. Today, new questions are being asked by agencies and special interest groups regarding the natural role of fire in wilderness and park areas. The opportunity to manage fire in the ecosystem as a natural event may be offset by politically generated realities. This presentation is aimed at stimulating new thinking regarding political concerns that may enhance or detract from fire management in wilderness areas.

Wildland fires that receive aggressive suppression action are seldom questioned by the greater number of citizens. In contrast, the management concepts in wilderness and park areas, where less than full suppression may be the objective, are often not understood nor fully supported, and are often challenged.

While the use of fire as a utility or a natural process in resource management has long been recognized as a valuable resource management tool, the recent public attention to its use has generated varied opinions ranging from full acceptance to focused opposition and distrust. These opinions, when communicated by the public, special interest groups, and the media, thereby influence the political reaction, and more recently pro-action, which can have dramatic leverage over the managerial discretion for prescribed fire and suppression strategies.

This paper discusses some of the realities, along with some intriguing management issues that relate directly to the politically influenced challenges in the future of fire management in wilderness and parks. It is intended to stimulate thinking of achievable wilderness fire management in the atmosphere of political reality.

## NEWS MEDIA COVERAGE

First on the list of realities is that news media coverage has reached an impressive level for real-time transmission world wide. One only needs to remember the Gulf War coverage where unprecedented live video was broadcast and the general public could witness American-launched missiles going by a hotel window and striking their targets in Baghdad. More recently the military beach landing in Somalia was greeted by the press with live cameras and lights.

The days of being able to tailor and control media releases to the specific desire of the authoring agency are really about over. The technical and administrative capability of the press means they are going to get the information they want, interpret it, and make the story as intriguing as the situation will allow. The management agency cannot overlook the need for close coordination with the media, and must be prepared for professional interface with their needs.

## PUBLIC REVIEW PROCESS

The mandated review process for management plans involves public reviews which, especially in the modern-day era, receive substantial oversight from local citizens and national-level interest groups. Now, better than ever before, the agency expectations for resource management plans with a fire component are printed and made available. The reviews allow for critique and comment. The final approved plan establishes the agency's solutions to any conflicts noted in the public review and becomes a record of the agency decisions.

Those opposed to any phase of planning, or outcome of execution, will not overlook the litigation value of the approved documents. From a political aspect, these same documents are binding obligations for the government agencies and become easy targets for politically inspired manipulation when conflicting issues arise over fire programs. This places emphasis on at least three areas that should be simple, basic rules for the development of any resource and fire management plan: (1) Say what you mean; (2) mean what you say; and (3) know what you have said. Poor administrative oversight and technical execution of a written plan may be the reason for opposition to your actions, but it will never be a valid excuse.

## GOVERNMENT INTERFACES

The third reality must certainly embrace the almost routine challenge between the legislative and executive branches of government. It must be remembered by any government agency that its roots are imbedded in the executive branch, which sharply enhances any political contrast the legislative branch may have with activities associated with fire management. Opportunity for partisan gain, influence on political platforms, and genuine support for constituents are components that may be interjected into the support or criticism for your fire management activities.

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## MANAGEMENT ASPECTS

Now that three basic realities have been identified, I wish to explore resource management-related aspects specific to wilderness and park fire management, which must be directly interjected into political arenas for resolution.

Definition of wilderness or park management areas, and the companion management plans, are generally oriented toward sustaining a defined ecosystem. Political designation of the areas does not always consider the management requirements prior to drawing the final boundary lines. Therefore, from a professional resource management concept, in consideration of what the political process has afforded wilderness and park management, I must consider the questions and observations by Steve Botti, Fire Management Program Manager with the National Park Service, when considering future research needs:

• "Are wilderness areas large enough for us to effectively manage wilderness fires, specifically prescribed natural fire programs that are designed to maintain 'natural' fire regimes?"

• "Did these processes previously operate on a true 'landscape' or 'ecosystem' basis, which cannot be sustained in the modern world?"

If the answer to the first question is no, then we must ask whether there can be true wilderness without the pervasive influence of naturally functioning fire regimes.

Consider the political ramifications for these provocative questions. The areas set aside by the legislative process have specific mandates; but, are they in fact configured in a manner that allows achievement of natural fire-supported ecosystems? If not, the agency faces a dilemma politically and ecologically.

One approach to this problem is through strong cooperative fire protection arrangements nationwide. With mandated interagency fire and resource management planning, it is imperative that we achieve effective multiagency plans for wilderness and park fire management.

Considering the political perspective, I pose more of Steve Botti's questions:

• "How do we integrate differing interagency mandates to develop programs that truly establish common wilderness fire objectives, similar to interagency endangered species recovery plans?"

• "How do we resolve conflicts between the philosophical and programmatic demands of wilderness fire management and other resource management programs, such as endangered species critical habitat protection, air quality management, and historic preservation?"

• "Do natural processes or natural and historic objects take precedence in wilderness areas?"

Naturally, answers to these questions will vary, depending on who is offering up the solution. These issues are now on our doorstep. We can no longer rely on the mystique of wilderness areas to fulfill the political and public support needed for realistic management plans. Nor can we expect the administrative boundaries to conform to natural processes.

Wilderness managers and supporters must directly confront the facts surrounding their ecosystems, and honestly approach the political arena with well-defined issues and alternatives. However, the economic realities must be recognized by managers while these alternatives are being formulated. To ignore them assures that the agencies will be confronted with well-earned criticism. A simple list can be made of the politically oriented economic and quality of life aspects that would influence the decision process for fire management in wilderness and parks:

- Nature vs. Jobs.
- Wilderness vs. Economic Interests.
- T&E Species vs. Progress and Development.
- Plants and Animals vs. Dollars.
- Natural Fire vs. Air Quality.

## POLITICAL PLANNING IS KEY

The time does not allow an indepth examination of all political opportunities and obstacles. However, these type of considerations must become specific objectives in our resource management goals for the future management planning.

Political planning must become a key ingredient to resource management plans and be integrated into interagency cooperation and community interests. This planning must include factual recognition of political sensitivity, strategy for dealing with it, and honest and realistic expectations for ecosystem management.

# Air Quality and Prescribed Fire: Striving for a Common Goal

Stanley G. Coloff

At first glance it may appear contradictory to suggest that prescribed fire and air quality share common goals. However, given the theme of this conference, it is very important, perhaps essential, to address the relationship between the selective use of prescribed fire and the protection of air quality and public health and welfare.

There are several areas of the country where we are now, or will soon be facing a most challenging natural resource management and air quality issue: public health and safety versus ecosystem health. Society demands the near-term resolution of this issue to first provide for the protection of public health. The long-term solution, however, is more difficult but must provide for maintaining ecosystem health. The 1990 Clean Air Act appears to place protection of air quality at higher priority than ecosystem health. This situation presents a significant challenge to air quality managers and natural resource managers.

Over the past decade prescribed fire and air quality protection issues have evolved from a primary focus on activity fuels (slash burning) to encompass the more fundamental and essential role of prescribed fire in maintaining ecosystem health.

Thus, the intent of this paper is to suggest that prescribed fire can be used in a manner that, on balance with wildfire, provides a net reduction in air emissions and a net improvement and benefit to air quality and public health, while maintaining the health of fire-dependent ecosystems. Idealistic? Perhaps, but certainly a goal of great importance to public health and ecosystem health.

## GLOBAL CLIMATE CHANGE

On a global scale, increasing efforts to develop strategies to reduce greenhouse gas emissions have focused on the destruction of tropical forests and the massive burns associated with land clearing to convert the land for other uses. Understandably, the growing public attitude in the United States, and perhaps the world, appears to be that all fire is bad and must be suppressed in order to save the planet from global warming. Unfortunately, the natural role of fire in the ecosystem appears to be overlooked by policymakers and may be swept away in the fervor to curtail the destruction and conversion of the world's forests. This is evidenced on the national and international level where global environmental policy options are being discussed to prevent both the destruction of the world's forests and to eliminate burning and emissions of carbon dioxide and other greenhouse gases.

## CURRENT CHALLENGES

Efforts to address prescribed fire, smoke management, and air quality management issues over the past 5 to 10 years have evolved in a positive and constructive manner in various regions of the United States. In the West, the Western States Air Resources Council, a non-profit association of the air agencies in the 14 Western States, has proven to be very effective in fostering open discussion among federal land management agencies, state government agencies, the Environmental Protection Agency, industry and other affected groups.

### Ecosystem Health

In October 1992, the Western States Air Resources Council conducted a "Forest Health-Air Quality Symposium" in cooperation with the USDA Forest Service and the USDI Bureau of Land Management to identify key technical and policy issues regarding the basic issue of the need for increased prescribed burning to sustain long-term ecosystem health and the need to maintain air quality standards to protect public health and welfare.

Many of the issues identified at the symposium are particularly relevant to prescribed fire in wilderness areas and national parks and help set the stage for resolving problems through more extensive dialogue, interaction and coordination among the federal land managers, state government agencies, Environmental Protection Agency, industry, interest groups and the public.

### Basic Air Quality—Prescribed Fire Issues

**Prescribed Fire-Wildfire Emissions Trade-Offs**—Is it feasible to demonstrate the "trade-off" between increased prescribed fire emissions and wildfire emissions?

The fire research community and the fire management community need to address this question as quickly as possible. The quantitative answer to this question is paramount; it would set the basis and framework for emission trade-offs between prescribed fire and wildfire, facilitate emissions trading programs and enable emission limitations to be offset.

A comprehensive study is needed to quantitatively determine the extent to which a net reduction of air emissions from wildfires can be achieved on lands treated with

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prescribed fire. The premise is that prescribed fires are typically of low intensity and consume less biomass and produce less air emissions than wildfire. As compared with wildfires, air quality impacts from prescribed fires can be better managed because prescribed fires are conducted in a manner that enables control of the fire at the burn site, a combination of burn techniques and smoke management practices are used to reduce fuel consumption, dilute and transport smoke emissions, and avoid sensitive areas.

**Significance of Increased Burning**—How much additional burning is needed? What are the likely emissions? What are the air quality and visibility impacts associated with smoke from increased burning and what requirements of the Clean Air Act and state air quality programs restrict or limit increases in burning?

Will the additional burning result in an air quality problem? It is important to understand the nature and extent of additional burning that may be required, areas of high priority for burning, and the anticipated time frame over which the desired burning is to occur.

**Regulatory, Administrative, Policy Changes**—What regulatory, policy, and administrative changes must be resolved to provide for increased prescribed burning? This includes changes in fire management policy and changes in state and local air policy and regulations.

## Conformity of Federal Actions to State Implementation Plans

The Environmental Protection Agency is in the process of developing regulations to ensure the actions of federal agencies conform to the state implementation plans.

Under the 1990 Clean Air Act, federal agencies have an affirmative responsibility to assure conformity with the state implementation plans. A federal agency's actions must not cause or contribute to any new violation of any standard, increase the frequency or severity of any existing violation, or delay timely attainment of any standard, emission reduction goal, or other milestone. Federal agencies are required to determine if their actions conform to the implementation plan. The conformity determination includes impacts of both direct and indirect emissions resulting from the action.

The proposed rule would apply to any area determined to be in violation of any of the ambient air quality standards; such areas are designated as nonattainment areas.

The requirement for a conformity determination would not apply to actions with emissions below specified minimum levels or to certain actions presumed to conform; for example, actions which require a process where an assessment of impacts on air quality and state implementation plan requirements would be completed (such as an environmental assessment or environmental impact statement).

In addition to any other procedural requirements, federal agencies must make their conformity findings available to the public for review. Notice of draft and final conformity analyses must be provided directly to air regulatory agencies and to the public through publication in the local newspaper.

The proposed rule is expected to be released for comment around March 15, 1993, with a comment period through April 15, 1993.

Conformity determinations are likely to place a substantial workload on federal agencies. It has not yet been determined how prescribed fire may be affected by the proposed rule. In our discussions with the Environmental Protection Agency we have taken the position that the prescribed fire planing process, including smoke management, should be considered as a process presumed to conform to the state implementation plan. The Environmental Protection Agency is considering this position.

## CONCLUSIONS

As has been said many times before, our world becomes more and more complex every year, and that complexity appears to make our jobs as stewards and managers of the public lands increasingly difficult and constrained by an ever longer list of regulations, notably air quality regulations.

Although it can be argued that protecting air quality is a constraint with regards to the use of prescribed fire, it is more realistic and productive in the long term to view air quality protection not as a constraint but as another operational factor as fundamental as understanding fire behavior and fire effects, and as essential as fuel for the drip torch.

The increasing complexity of land management in general may also be viewed from the positive perspective as an "indicator" of our evolving understanding and appreciation of the complex interactions within the human environment and ecosystems we manage.

# The Federal Clean Air Act and Its Impact on Fire Management Programs

**Brian Mitchell**

Potential air quality constraints with respect to fire programs in parks and wildernesses are a real concern. The basis for most air quality programs is the Federal Clean Air Act and its last two major amendments in 1977 and 1990. Other air quality requirements may arise from the passage of State or local laws and could be equally important from the standpoint of fire managers.

Considering that smoke impacts from fire activity can interfere at times with attainment and maintenance of air management goals, there are some potential conflicts between fire and air quality programs. It is likely that these conflicts are not unresolvable and that the use of fire in natural areas where it is needed will not be eliminated—but it is also likely, and already a reality in some parts of the country, that fire programs will incur greater costs and possibly take more time to successfully accomplish their goals and objectives due to air quality considerations.

Internally, the National Park Service has addressed air quality and smoke management needs through revision of its Fire Management Policies Guideline, NPS-18 (NPS 1990). Among other things, the guideline discusses the legal requirements for air quality which must be met by smoke management programs and recommends how program managers should work with air regulatory boards and agencies. Both topics will be discussed by speakers on this panel.

A brief overview of current Federal Clean Air Act requirements having the greatest potential for affecting fire management programs is presented in this discussion. Others on the panel will provide information on how some of these requirements are actually met or carried out and how the development of regulations and programs to accomplish these requirements can be influenced before they are imposed on fire management agencies.

## FEDERAL CLEAN AIR ACT

The Clean Air Act (Act) mandates air regulatory programs that are administered either by the Environmental Protection Agency (EPA) or State and local air quality agencies. The EPA initially develops Federal regulations consistent with requirements of the Act, then these regulations are administered at Federal, State, or local levels. State and local air quality agencies are given authority and funding under the Act to adopt and implement these programs in air quality plans, called State Implementation Plans. It is through these implementation plans that State and local governments are assigned primary responsibility for implementing and enforcing federally established air pollution control requirements.

A basic requirement under the Act is the establishment and enforcement of national ambient air quality standards for specific pollutants (called criteria pollutants) to protect public health and welfare. Many other Clean Air Act requirements and programs are related to and support the attainment and maintenance of these ambient standards. Only in very rare instances (such as exceptional events of natural origin) may any of these ambient standards be violated without corrective action being required of a culpable air pollution source (EPA 1986).

Prior to 1990, the Act did not explicitly address prescribed fire as a source of air pollution. However, the 1990 amendments to the Act contain several sections which may result in both direct and indirect regulatory control of prescribed fire.

### Section 112 - National Emission Standards for Hazardous Air Pollutants

Currently, this section of the Act applies to the traditional stationary source categories that emit hazardous air pollutants (such as power plants and paper mills). Because wood smoke contains several hazardous air pollutants among the 189 pollutants listed in the 1990 amendments to the Act, the potential exists for future consideration of wildland fire as a major source of these pollutants. Indeed, the EPA has already commissioned a study to help quantify certain hazardous air pollutants emitted by prescribed fire (Ward and others 1993).

### Section 116 - Retention of State Authority

While the EPA's regulations specify minimum requirements to be included in State implementation plans, there is often some flexibility and discretion at State and local levels to tailor these Federal regulatory programs to meet varying local conditions and needs. This section of the Act allows States to develop standards and regulations that are more stringent than federally required, but they can be no less stringent. However, many States are prohibited by State law from adopting air quality control requirements more stringent than those mandated by the EPA.

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## Section 118 - Control of Pollution from Federal Facilities

This section directly affects Federal facilities, activities, and properties which discharge, or may result in the discharge of, air pollutants. It requires Federal government agencies "to comply with all Federal, State, interstate, and local air quality regulations...in the same manner, and to the same extent as any nongovernmental entity." The Act clarifies that this language applies to meeting any substantive or procedural requirements (such as record keeping and obtaining permits) and complying with any process and sanctions exercised by any Federal, State, or local administrative authority or the courts.

The 1990 amendments to the Act include new language specifying that affected Federal agencies shall pay a fee or charge imposed by any State or local agency to defray the costs of its air pollution regulatory program. Some localities and States currently have programs requiring the issuance of burn permits and collection of fees for prescribed fire programs administered by Federal agencies, and it is likely that more States will consider adopting similar requirements.

## Section 169A - Visibility Protection for Federal Class I Areas

This section, which originated in the 1977 amendments to the Act, provides special consideration for visibility protection in designated mandatory Federal Class I areas. These areas include large national parks (exceeding 6,000 acres) and wildernesses (exceeding 5,000 acres) that were in existence prior to August 7, 1977. The 1990 amendments to the Act clarified that Class I area boundaries will conform to any boundary changes which occurred subsequent to the 1977 amendments or which occur subsequent to the 1990 amendments.

The Act establishes a national goal of remedying any existing and preventing any future manmade visibility impairment in mandatory Class I areas where visibility is an important value. Implementation of the EPA's visibility regulations to date has primarily focused on preventing adverse impacts on Class I area visibility due to emissions from new major stationary sources or from major modifications of existing sources of air pollution. Recently, more attention is being given to the existing and potential effects on visibility due to smoke from fire activity in States where fire is a significant source of airborne particulate matter and where Class I areas are nearby (such as Oregon and Washington).

Of particular interest with respect to the fire community is the possible interpretation by air regulatory agencies that smoke from prescribed natural fire is manmade air pollution. In the absence of any explicit EPA policy on this issue to the contrary, State and local agencies may well look to include prescribed natural fire emissions, in addition to management-ignited prescribed fire emissions, in their inventory of pollutants and sources which could be further controlled to help achieve the national visibility goal. This section of the Act defines "manmade air pollution" as "air pollution which results directly or indirectly from human activities" and allows some room for interpretation as it pertains to the management of prescribed fire.

## Section 169B - Visibility

The 1990 amendments added a new section on visibility protection that, among other things, established the Grand Canyon Visibility Transport Commission to address regional haze affecting the Grand Canyon and other Class I areas in the Colorado Plateau. The Commission is considering all potential sources of visibility-impairing emissions, including silvicultural and agricultural burning, in assessing the causes of visibility impairment affecting these Class I areas. By November 1995, the Commission will issue a report of its findings to the EPA and the public with recommendations for a regional haze control program needed to make progress toward the national visibility goal in Colorado Plateau Class I parks and wildernesses. Other multi-state visibility commissions are authorized by the Act to address Class I area visibility impairment which may be caused by interstate transport of air pollutants.

## Section 190 - Issuance of Reasonably and Best Available Control Measures Guidance

This section was added by Congress in the 1990 amendments to deal with certain non-traditional sources of air pollution which may contribute to non-attainment of the PM-10 (particulate matter less than 10 microns in diameter) ambient air quality standard. "Prescribed silvicultural and agricultural burning" was one of three specific source categories for which the EPA had to issue technical guidance regarding reasonably available control measures and best available control measures (EPA 1992). This guidance was issued by the EPA in September 1992 and may be used by State and local air quality agencies in developing control strategies to attain and maintain the ambient standards for PM-10. Prescribed fire, regardless of the ignition source, may be considered for regulation under this guidance if it contributes to an area's non-attainment problem.

## CONCLUSIONS

Recent amendments to the Clean Air Act have given more explicit attention to prescribed fire as a controllable source of air pollution. In the development and implementation of State and local air pollution control programs, prescribed fire has also received more attention in areas where effective smoke management is necessary to help achieve air quality goals. Cognizance by fire managers of air quality goals and requirements coupled with good smoke management practices in the field to minimize air pollution impacts will help assure the viability of prescribed fire programs in the future. If smoke from fire is managed consistent with air quality needs, regulators will have little reason to seek new laws or use their existing discretionary authority to tighten regulations and policies affecting fire activities.

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# Prescribed Natural Fire and Air Quality: Identifying The Real Problem

**Marian S. Chambers**
**Edward A. Duncan**

In recent times, prescribed fire has been utilized for over two decades to manage wilderness vegetation in the Sierra Nevada. In National Parks, both naturally ignited and management-ignited prescribed fires have been effectively managed to reduce the fuel buildup that accompanied years of fire suppression, and to maintain the natural influence of fire in wilderness. This most effective program is in danger of serious setbacks due to conflicting legislation, which precludes local land managers and agency personnel from reaching a mutually acceptable and legal agreement. The Wilderness Act and the Clean Air Act are at odds, as is the legislation that created National Parks. Interpretation concerning the intent of law may yet be required to bring this issue to solution; however, compromise and good-faith working relationships must suffice for now to keep both programs intact.

The western slope of the Sierra Nevada contains the fastest growing communities in California. Population has doubled in the last 7 to 10 years. The population moving into these areas is largely made up of the retirement or near-retirement age class that is tired of the overcrowded cities. They are a group who, due to their age, are very knowledgeable in the law and the responsibilities of agencies both state and federal. Air quality is one of the main reasons people moved, accompanied by the desire to live nearer to the less populated recreation areas of National Forests and parks. The open space between the developed zones and the wilderness areas of the Sierra Nevada Range is rapidly diminishing and for the most part is largely gone. Almost all towns of over 2,000 people have bedroom neighborhoods, like satellites, of houses on 3- to 5-acre parcels. The most desirable areas are directly adjacent to federal land that can't be further developed.

## PUBLIC PERCEPTION

Areas that traditionally were burned off several times over the years are now so close to neighborhoods that the use of fire for maintaining a respectable fuel loading is not even considered on a large scale. The land managers' ability to prescribe fire is further encumbered by the impacts of smoke. These newcomers don't differentiate between the sources of smoke, whether it's from wildfire, prescribed burning or naturally ignited wilderness fires. They have a hard time understanding why they cannot burn their own plant material when a large agency is allowed to continue burning and impact their comfort, visibility and daily routine. Even though the public has been bombarded with information on the benefits of fire, the impacts of smoke during the summer generate a large amount of complaints. This could also be attributed to fears instilled by the Stanislaus Complex Fires of late August 1987 that burned 140,000 acres in Mariposa and Tuolumne counties. These complaints, from knowledgeable people, go directly to the employees of the County Air Pollution Control Districts, who are obligated to locate the source, determine the impact, and legally deal with the problem.

## CALIFORNIA LAWS AND REGULATIONS

In California each county can be considered a separate Air District. While some counties have, through agreement, unified to create Unified Air Districts, some have not. The county is the lowest level of regulation and rule making and, while a county or group can make more restrictive regulations, they cannot make less restrictive regulations than those already present at the state level.

The Health and Safety Code for California defines agricultural burning as: the use of open fire to manage habitat, cropland, roadway vegetation, or canal systems, or for forest management, range improvement and wildland vegetation management. Wildland vegetation management is the use of prescribed burning by public agencies or through cooperative agreements or contracts involving a public agency to burn land predominantly covered with chaparral, trees, grass, or standing brush. Prescribed burning is the planned application of fire to vegetation to achieve any specific objective on lands selected in advance of that application. The planned application of fire may also include natural or accidental ignition (Chapter 2, Section 39011 a-c, California Health and Safety Code).

Prior to 1987 there was no distinction between prescribed natural fires and prescribed burning in the California Health and Safety Code or in the California Code of Regulations. Prescribed burning was separated into Forest Management Burning (activity fuels only), and Range Improvement Burning (Habitat or Range improvement burning) (Title 17 California Code of Regulations: Part III Air Resources, Subchapter 2, Agricultural Burning Guidelines).

In 1987 the Health and Safety Code and the California Code of Regulations were revised to include Wildland Vegetation Management Burning (activity and natural fuels),

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which was used to identify burning of all types by public agencies. The 1987 regulations were the first evidence of a requirement for burn plans, fuel loading, smoke management considerations, and specification of monitoring.

One of the requirements for burning is that a permit be acquired and that the burn be on a permissive burn day in accordance with the California Health and Safety Code Section 41854. The section states: "This permit is valid only on those days during which agricultural burning is not prohibited by the State Air Resources Board pursuant to Section 41855 of the Health and Safety Code." Section 41855 states that "the state board shall determine and designate from meteorological data the days when agricultural burning shall be prohibited within each air basin." These data are defined in Title 17 of the California Code of Regulations Section 80290, which states the criteria for permissive burn day status within the air basins. As defined in the California Code of Regulations, the permissive burn day requirement is limited to elevations below 6,000 feet in elevation. This elevation was originally 3,000 feet when the only area of concern was the California Central Valley. Recent studies of regional movement of pollutants have a major bearing on these figures. An area burning above 6,000 feet and having a strong impact to a population at 4,000 feet is a continuing problem.

A variance may be granted on a no-burn day by the local Air Pollution Control District and the California Air Resources Board under strict guidelines of California Health and Safety Code Section 41862 and Section 80120 (d) of Title 17, California Code of Regulations. The Agricultural Burning Guidelines allow a district to authorize, by special permit, agricultural burning on days designated as no-burn days "when denial of such a permit would threaten imminent and substantial economic loss." Section 80120 (d) also requires a district to limit the amount of acres which can be burned on any one no-burn day and to "only authorize burning when downwind metropolitan areas are forecasted by the Air Resources Board to achieve the ambient air quality standards".

## THE CONFLICT BETWEEN AIR AND FIRE

The primary management goals for utilizing fire in wilderness areas and parks have been well defined and the direction has been clear for some time. One has only to review the proceedings from the 1983 Symposium and Workshop on Wilderness Fire to find a multitude of reasons why this tool must be utilized to the maximum extent possible. A tremendous amount of support led to the start up of new programs in many parts of the West over the last decade. The events of the summer of 1988 displayed the magnitude of ecological change that could result from these programs, and is recognized by most wilderness managers as a positive ecological event for this particular ecosystem. These events however, occurred on a much grander scale than anyone could have foreseen, and affirmed that there was still more to learn. Strengthened by the desire to continue, and with new questions concerning these events, the summer of 1988 resulted in an incredible resurgence of interest in fire and fire programs. New research and intensified focus on these questions followed immediately and smoke was one of the issues that started to receive attention.

The Interagency Fire Management Policy Review Team affirmed the basic concept of fire in wilderness, and recommended many changes that would lead to programs with a higher level of integrity. Neither the 1983 proceedings nor the Review Team's final report thoroughly dealt with the smoke problem. Haddow's paper, which was the only smoke management paper in the 1983 proceedings, warned of the problems ahead as population increases in each area. The problems between fire for wilderness management and air quality are still unresolved and will remain so until some significant modifications are completed.

The real problems regarding this issue are related to the conflict in laws. The current and future emphasis on total ecosystem management will require that certain issues be clarified at the national and congressional level. Legislative relief from conflicting laws must be paramount before total ecosystem management can be realized. The intent of the Clean Air Act was to limit pollutants from human-made sources, yet we find that it has been interpreted and made applicable to lightning ignitions due to lack of initial clarification.

## PAST LESSONS

In early September in 1991, a relatively quiet fire season, lightning ignited a flurry of fires in Yosemite National Park and throughout the Sierra Nevada. Several of these fires were authorized as Prescribed Natural Fires and two became sizable enough to cause serious smoke concerns. The Frog Fire on the northern part of Yosemite was the first to draw concern. After about two weeks of slow rates of spread it began to make gains of 150 to 200 acres daily. While this was not of particular concern, the weather pattern was. Light easterly breezes each night were moving the day's emissions into the central valley and, more specifically, the towns of Tuolumne County. Casual inquiries to the local Air Pollution Control District started and became increasingly more hostile. This persisted for a period of several days to the point where local lookouts were reporting minimal visibility until as late as 1300 to 1400 hrs. The concern grew among the neighboring agencies that an ignition could possibly go undetected and become a major problem. A forecasted cooling trend failed to materialize and a decision was made to step in and take action on the Frog Fire to reduce emissions. Two crews plus a spike camp operation were flown in to stop the spread along the western flank of the fire, which was a mile and a half wide. The fire was converted to a wildfire at a size of 950 acres and an indirect attack and burn out secured the west flank in four days. Because of the nighttime easterly winds, an additional crew had to be utilized, as did a helicopter which was logging on the forest nearby. The eastern perimeter was managed in a confine strategy and continued to move slowly into higher country for the next month. The emission-producing western flank was controlled and mopped up. This fire ended at 3,500 acres and cost close to $90,000 to suppress. The duration of the smoke incident was about 13 days, 7 of which were no-burn days, and smoke ranged out about 100 miles into three counties. The second incident was the Ill Fire, which was suppressed entirely, but

had contributed to the smoke load during the same period. Between the two fires the capacity of the airshed had been exceeded, as had the tolerance level of the local community.

In November 1991 Yosemite National Park was asked to discuss the incident at a Smoke Management Committee meeting in Sacramento, California. This committee is an offshoot of the California Air Pollution Control Officers Association and meets monthly at a conference room in the Office of the California Air Resources Board (CARB). From that meeting it was apparent that some serious information sharing was needed, as many of the association's members had no idea of the importance of wilderness fires. It was just as clear that agency land managers needed to at least consider a compromise that would be mutually acceptable. The park volunteered to give a more formal presentation concerning the program at the December meeting in order that more members could be present and understand the importance of the program.

Throughout the winter more and more people were drawn into the loop, from various levels of the organizations, to study the conflicts between the various acts and laws involved in setting up and managing parks and wilderness areas. Attempts were made to establish a Memorandum of Understanding or Agreement or Conditions of Permit, that would act as a compromise and legalize the situation. Nothing could be agreed upon officially. There was intent on both sides to have something finalized, but there was jurisdictional responsibility to consider. To this day there is no written agreement; however, there is understanding of the real problem, and there is the desire to continue our progress toward the solution.

## FUTURE OPPORTUNITIES

The smoke episodes in 1991 convinced the parties involved that two types of monitoring data were needed. The first was particulate concentrations related to the event, and the second was local meteorological data that could be used to determine burn-day status.

Particulate concentrations are measured by sampling stations certified by the Environmental Protection Agency that have been utilized in different locations in the counties for the last several years. In 1992 a new Tapered Element Oscillating Microbalance was rented for testing and later purchased, to get baseline figures for particulate concentrations in Yosemite Valley only. In the event of a natural fire impacting the area, by smoke drift, the data will allow an accurate comparison to assist management in the decision making process. The microbalance is currently the most accurate instrument for measuring real-time particulate concentrations. An attempt to collect baseline data within park villages is underway within Yosemite National Park. This instrument was purchased with the intent of making it mobile enough to move to areas where impacts may occur, depending on the concentration and trajectory of the smoke. This data alone would assist management in predicting when to implement a holding action to reduce a fire's emissions and to avoid a major impact in the future.

The second type of data is much more costly to obtain, but would provide much better burn-day calls by the Air Resources Board. Funding for a meteorological station capable of giving upper air information and for an employee to operate the station is lacking at this time, but would be of great value to all agencies involved in prescribed fire. A share-cost package for funding this type of instrument is being strongly considered; however, budget constraints preclude this plan in the immediate future.

The true challenge of the future lies in creating an understanding that health of the environment is a high priority. If managing wilderness is to include allowing all natural processes to interact, then fire certainly must be part of that interaction. Smoke from prescribed natural fires will impact certain areas during the summer months just as it has for eons. If prescribed natural fires mean a healthier, more natural environment, then they should be allowed to occur, regardless of burn-day status. If, on the other hand, the smoke causes health and safety concerns, action should be taken to reduce the emissions. This is the gray area that is not dealt with by law. In shifting our management to focus on entire ecosystems there may yet be another round of legislation ushered in to clarify these gray areas. This legislation should be structured with full cognizance of the current conflicts in land management law, and must be supported at the highest levels of management. Congressional support must be won by upper level management and it must be started now.

## SUMMARY

Prescribed natural fire programs adjacent to heavily populated areas are threatened by conflicting laws. Until relief is found through new legislation, wilderness fire managers must be constantly aware of smoke drift and its impact on adjacent areas. It will be wise to monitor particulate concentrations, track emissions, and utilize every tool available when managing natural fires. Continued communication and development of sound working relationships based on trust and compromise are essential at this point. There is room for give and take to keep this most valuable tool viable.

# Involvement of Wilderness and Park Fire Managers in Developing Air Quality Regulations


## Dennis Haddow


Fire in wilderness and park ecosystems is a large, intermittent source of particulates that can have significant short-term impacts on fine particulate concentrations and visibility. This presents a serious challenge for wilderness and park managers who must address the potential conflict between the ecological need for using fire as a management tool and the public's desire for clean air and good visibility. Air quality standards and regulations from both a national and State level are becoming more stringent and have the potential to severely limit the use of fire in fire dependent ecosystems (Lahm and others 1992).

At the same time that air quality regulations are becoming more stringent, the ecological need for the use of prescribed fire is increasing in many parks and wildernesses. Fuel loadings are increasing to unnatural levels, unnatural successional changes are occurring, and biodiversity is being unnaturally altered (Brown 1989). These unnatural changes are in direct conflict with statutory park and wilderness management direction.

Air quality regulations and standards will never "take away" the use of prescribed fire. However, we may "give away" the use of prescribed fire if we, as fire managers, do not do a good job of smoke management. This includes becoming aware of existing and potential air quality challenges, becoming active in the development of air quality regulations, creating an awareness with air regulatory agencies and the public about the ecological role and tradeoffs for prescribed fire, and providing leadership in changing the current single media environmental protection system.

## THE AIR REGULATORY CONTEXT

In order for fire managers to meet the challenges provided by existing and potential air quality regulations, they must understand the context in which air quality regulators operate, at both the Federal and State levels.

Fire managers need to consider that air quality regulators do not manage ecosystems, they manage a specific medium, air. This creates a significant challenge for ecosystem managers who must consider all influencing media along with the physical, chemical, biological and social resources and ecosystems they impact. It has been recognized that real solutions to environmental management problems can not be solved through segmented or fragmented regulatory approaches (Bartlett 1990). It is currently possible and even probable that the control of one environmental problem such as air pollution will contribute to other environmental problems such as the loss of biological diversity or catastrophic wildfire.

At the Federal level, the Environmental Protection Agency is just beginning to develop multi-media environmental protection programs which, in the future, may be able to better consider issues such as fire in wilderness ecosystems. However, the development of comprehensive environmental decisionmaking processes to address the problems caused by single media protection programs may require the modification or elimination of existing institutional and statutory constraints. Wilderness managers should consider what role they want to take (leader, follower, or non-participant) in proposing changes to existing statutory, regulatory, and institutional programs that focus on individual media. It is these potential changes to the existing single media regulatory system that may truly determine the future of prescribed fire in parks and wilderness.

Prescribed fire managers have often stated that air quality regulators must understand the role of fire before they develop air quality standards and regulations. This is only partially true. Air quality regulators do not have to understand the role of fire in the ecosystem to do their jobs. That is, in order for air quality regulators to meet the objectives of Federal and State Clean Air legislation they do not have to be aware of or sympathetic to the objectives of the Wilderness Act, Organic Act, or of the role of fire in the ecosystem. However, in order for wilderness managers to do their jobs it is imperative that they effectively communicate the role of fire in the ecosystem to air quality regulators. That is, air quality regulators can do their jobs without park and wilderness managers, but park and wilderness managers can not do their job without the support of air quality regulators. It is imperative that park and wilderness managers take the lead in facilitating communication with air regulatory agencies.

Park and wilderness managers need to develop programs on a local basis to manage smoke from each park or wilderness. Each local program should include a specific strategy that identifies what the wilderness manager is doing to make it as easy as possible for air quality regulators and the public to say "yes" to fire programs. This strategy should include an intense, well-focused communication plan. When trying to communicate the role of fire in the ecosystem to the public, park and wilderness

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managers must speak in terms that the public understands. For example, even terms like natural succession are not commonly understood. (Changing natural succession through exclusion of fire will not influence Prince Charles becoming king.)

Basically, wilderness and park managers need to work to make sure that politically correct air quality regulations are also ecologically correct air quality regulations. This is a challenge because the general public understands the need for clean air better than they understand the ecological needs for fire in parks and wilderness.

## THE AIR REGULATORY DEVELOPMENT PROCESS

In order to be effectively involved in the regulatory development process, park and wilderness managers must understand how the process works and where involvement is most useful. Administrative rule making is the exercise of quasi-legislative authority by a governmental agency to formulate, amend, or repeal a rule. The end product has the force of law. As required by section 118 of the Clean Air Act, Federal agencies must comply with all substantive and procedural requirements of Federal, State, and local air quality regulations and standards. That is, Federal agencies must comply with all parts of all regulations developed by administrative rule making at State and local levels. Administrative rule making can be divided into three separate phases: the legislative phase, the proposal and review phase, and the hearing phase.

### Legislative Phase

Prior to rule making by any administrative agency, statutory authority must be provided by the legislature. For air quality issues, the statutory authority is usually provided in the State Clean Air Act. When authority is inadequate, public and interest groups need to direct their efforts toward either lobbying the legislature or persuading the administrative agency to seek authority. Such lobbying is also appropriate when the public or interest group feels that the administrative agency has too much authority and is developing regulations that are not appropriate. It is very appropriate for park and wilderness managers to be actively represented in the legislative phase.

### Proposal and Review Phase

Administrative rule making requires a formal process for public review and comment. Park and wilderness management agencies are an important part of the public that needs to be represented. Typically, an administrative agency develops proposed regulations in-house, notifies the public and interest groups of its proposal, provides a review period, and conducts a public hearing to solicit comments on the proposal. Administrative rule making procedures vary from State to State and sometimes from agency to agency within a State. It is important that park and wilderness managers understand the appropriate administrative rule making procedures before the procedures begin.

Often, regulations are adopted exactly as proposed by the administrative agency. Therefore, the most effective time for park and wilderness managers to become involved in the rule making process is before the agency develops the proposed regulations in-house. After proposed regulations are developed and proposed in draft form, it is only natural that an administrative agency will feel that they have something to defend. Comments received after a draft is proposed are often considered in an adverse light. It is only human nature that administrative agency staff (or anyone else) might find it difficult to objectively review comments that are critical of their efforts. Again, the most effective time for park and wilderness managers to become effectively involved in the rule making process is before it formally begins.

### Hearing Phase

After an air regulatory agency develops and proposes a regulation, there is usually a time period for public review and a subsequent public hearing. Public hearings are probably one of the worst possible places to exchange new concepts and ideas. However, public hearings are a good place to reinforce concepts and ideas that are already established. Public hearings can be an excellent opportunity to bring in support and testimony from other groups which may support the land manager's position. Other groups may include industry, environmental organizations, and fish and wildlife agencies. Finally, the more supportive that park and wilderness managers can be of the air regulatory agency during the public hearing, the better the relationship between the groups will be in the future.

## PROVIDING INFORMATION TO THE PUBLIC AND AIR REGULATORY AGENCIES

A major problem that land management agencies must overcome is that air quality agency staff usually do not have an understanding for the needs and uses of prescribed fire. While air quality agency staff have excellent understanding of control equipment for stationary pollution sources, they often have little understanding of biological processes and the natural role of fire in driving those processes. As a result, it is possible that air quality regulations will be proposed for which the air quality staff does not understand the full consequences.

In order to take care of this and other problems, it is necessary for wilderness managers to inform air regulatory agencies on the uses and needs for prescribed fire. This education can done in meetings initiated by the wilderness manager or preferably by field trips and actual involvement in prescribed burning. One day in the field is usually worth 10 days of meetings. However, it is important that meetings and field trips take place before the air regulatory agency proposes regulations.

Park and wilderness managers also need to inform air regulatory agencies and the public on smoke management techniques that are available and how various smoke

management techniques relate to specific burning prescriptions. It is important that the air regulatory staff understand that the smoke management technique that is selected must fit the specific burn prescription.

It is also critical that park and wilderness managers establish credibility with the air regulatory agency before regulations are proposed. It is much more difficult to develop credibility with any type of regulatory agency after the regulatory process has begun. In most cases, air regulatory agencies view fire managers the same way that they view any other polluter. These same air regulatory agencies have heard hundreds of excuses why specific polluters should be exempt from regulations, why it is too expensive to comply, why the polluter doesn't really cause any problem, why someone else is the real problem, and generally why the whole world will go to hell if the polluter is required to do anything. Rather than try to make lame excuses, park and wilderness managers will develop credibility with air regulatory agencies if they can demonstrate how they are doing the best possible job of minimizing both the amount and impact of the smoke they emit into the air, given the constraints of ecosystem management. As with all issues concerning park and wilderness management, credibility is our most important management tool.

The key for fire managers to be effectively involved in the regulatory development process is to be both proactive and credible. Being proactive and developing credibility take time and effort. However, if park and wilderness managers want to continue to use prescribed fire as a management tool, taking the time and making the effort are an absolute necessity.

## SUMMARY

If park and wilderness fire managers are going to meet the challenges provided by both existing and potential air quality regulations, they:

- Need to be aware of their legal responsibilities under clean air legislation
- Need to be sensitive to air quality issues and concerns
- Need to be aware of potential changes to air quality standards
- Need to be active players in the air regulatory development system
- Need to provide information to and develop credibility with air regulatory agencies and the public
- Need to provide leadership in changing existing statutory and institutional programs that provide for single media protection rather than ecosystem management
- Need to develop strategies that make it as easy as possible for the public to say "yes" to wilderness fire plans.

Protection of air quality, including visibility, is good. Perpetuation of natural ecosystems through the use of fire is good. However, it is incumbent on park and wilderness managers to take the lead in developing programs and relationships to make sure that these programs do not conflict with each other. Otherwise, we may "give away" our ability to use fire as a park and wilderness management tool.

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# Predicting Fire Effects on Rare Plant Taxa: a Management Perspective


## Anne Marie LaRosa
## M. Lisa Floyd



**Abstract**—The Endangered Species Act elevates the protection of rare taxa above most other management objectives on Federal lands. In determining the relative importance of rare taxa preservation to fire management goals, the manager is faced with a compromise, which can only be adequately addressed from an understanding of the fire adaptations of the rare plant and the fire regime under which that plant evolved. Such data are rarely available. Discusses the types of data that are available, the sources of this information, and plant adaptations to various fire regimes. Two specific examples, from Mesa Verde National Park and Buenos Aires National Wildlife Refuge are presented on how to use preliminary information on rare plant adaptations and wildfire regimes in fire management decisions.


There is rarely a simple means of balancing the management of resources on public lands. When certain biotic resources gain special status because of their rarity, the balance shifts in their direction. Under Section 7 of the Endangered Species Act, actions of Federal agencies cannot jeopardize the "continued existence of threatened or endangered species or result in the destruction or adverse modification of their critical habitat." As it exists, the Act may put constraints on, for example, wilderness management. It applies to all Federal lands and strictly speaking supersedes wilderness management priorities. Planning for species conservation and, more important, to increase recovery goals often requires setting endangered species goals higher than wilderness management goals when potential conflicts arise.

To meet the legal obligation to protect threatened and endangered (T/E) species, managers need to anticipate the probable responses of these species to a given fire regime or fire prescription in the case of management-ignited fire. In doing so, the agency is directed to use the *best available scientific and commercial data to determine if a species may be in jeopardy due to the Federal action*. Such decisions are problematic given the lack of specific information on the biology and ecology of many of these taxa. Even less is known about the effects of fire on these species.

As evidence of the paucity of detailed information available, nearly half of the papers in a recent conference on rare and threatened plants of the southwestern United States were limited to distribution information (Sivinsky and Lightfoot 1992). There was an overwhelming consent among these authors that survey alone, although a first step, will not suffice toward understanding how to protect a rare species. Adding fire effects to the list of threats imposed on these species is a relatively new concept; only one paper out of 32 discussed fire effects. It is likely that these data will become available in the future but for now, how should we proceed?

The adaptations of rare plants, such as T/E species, to fire are generally the same as those of other plants. Fire resistance, mortality, response mechanisms, and postfire recovery likely follow the same principles for rare plants as for other plants with similar adaptations. The primary difference when considering management options is that these plants are few in number and often have very restricted habitats. Therefore the consequences of our actions, in this case the use of fire, take on greater significance.

For some wilderness areas we may argue that fire is natural and hence necessary and that species within those habitats benefit from fire. In the case of early successional species they may even be threatened by the lack of fire. Even within rather large wilderness areas, internal and external influences are at work: habitat fragmentation; inadequate preserve design; fuel alteration by fire exclusion, livestock grazing, and the introduction of exotic plant species; and socio-political concerns such as air quality. These influences often hamper or prohibit the functioning of large-scale natural processes such as fire. So while fire is theoretically indispensable to many ecosystems the "reality is more complex" (Pyne, these proceedings). Indeed, the role of natural fire in wilderness may only be definable in the context of the larger cultural landscape within which it operates. When managing rare plant species we must scrutinize the components of natural fire. Wilderness managers are increasingly faced with the choice between allowing an area to respond to a natural disturbance, such as fire, and the potential consequences of the lack of intervention, many of which have become unacceptable (Christensen 1991). Our current wilderness fire policies illustrate such constraints—fires within wilderness areas are not allowed to burn spontaneously but burn within prescription parameters that often limit the range of fireline intensity, size, and effect on the landscape.

As early as 1916, Jepson noted that only those species of manzanita (*Arctostaphylos*) with a basal burl sprouted after fire. Later this relationship was shown to be characteristic for other genera in the chaparral community (Keeley and Zedler 1978). Subsequently, additional ecological adaptations to fire that aid in plant survival have


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been documented. Species adaptations, such as fire-stimulated reproductive characteristics, were summarized for Pacific Northwest forests (Kauffman 1990). More recently a series of publications (Bradley and others 1992a; Bradley and others 1992b; Crane and Fischer 1986; Fischer and Bradley 1987; Fischer and Clayton 1983) rated the relative fire resistance of species in Intermountain forest and woodland habitats using observable morphological characteristics such as bark thickness and root habit. A similar study focused on morphological adaptations of western shrubs including characteristics adaptive to individual survival, such as crown resprouting, and those which may aid in a population's survival, such as postfire seed invasion (Noste and Bushey 1987).

Ecological adaptations and principles of plant response to fire can be applied to predict the postfire effects of species for which we have little detailed information. In evaluating possible plant adaptations and responses to fire, what types of information should you gather and what are the possible sources of that information? We can break the information needs into three general categories: knowledge of (1) plant distribution, (2) the habitat, including the past and present fire regime(s) of the area, and (3) specific plant adaptations. We would like to predict the relative ability of the plant to survive fire and the mode of reproduction following fire for all plants. For rare taxa, we must also understand the cumulative threats to the species' survival and the contribution of fire to those threats.

# THE RISK ANALYSIS

The manager performs a risk analysis—balancing the benefits of natural fire with the necessity of protecting those resources at risk from the fire. But in the case of threatened or endangered species, the natural resource values at risk are among the highest and most difficult to plan for. Given these considerations, how should one proceed? Rather than attempt a thorough search of the literature, we will use selected references and two management examples to discuss the types of information needed and associated considerations for the use of fire.

## Basic Demographics

What is the taxon's distribution and abundance, including the number of individuals and populations? Include information on land ownership of the various populations and their protective status. What proportion of the total plant distribution is in your management area? And do you have the only protected population of this plant? The justification for your action and the necessity for accurate predictions would likely increase with the rarity of the taxon and the threats to its existence.

## Habitat Characteristics

**Fire Regime**—What is the historical fire regime, including the range of fire size, fire intensity, and fire return interval? When is the historical fire season? How have human activities such as fire exclusion, landscape fragmentation, and alteration of fuels and ignition patterns affected the fire regime? What other natural disturbance events, such as hurricanes or infrequent but severe frost, have occurred that may affect the fireline intensity (heat released per unit of time for a unit length, burn severity (amount of heat directed toward the ground), or fire frequency?

**Microsite Differences**—The role of habitat heterogeneity cannot be understated. Compare the fire potential of the habitat type with the microsite conditions under which the plant is found. What is the ability of the microsite to burn and how intense might the fire be? Are there microhabitat differences in fuel loading, continuity, or fuel moisture, particularly in relation to rare plant distribution? Fires often burn in a mosaic pattern with varying fire frequency, fireline intensity, and burn severity even within a local area, resulting in divergent fire effects. This is of vital concern when evaluating species with limited distribution—that is most T/E plant taxa.

## Departures From The Norm

Finally, it is important to understand the deviations from the natural or historical fire regime to which the taxon may have adapted. In particular, are the ranges of current values of such factors as fireline intensity, burn severity, and fire frequency—including those in your prescription alternative(s)—within the range to which the species have adapted? If a species is present, it has obviously survived the historical fire regime or may exist because of fire exclusion. In either case, it is critical to determine if the fire regime has been altered, making it vulnerable to fires in the future.

## Plant Adaptations To Fire

What could you predict about potential adaptations to fire? Plant adaptations vary, and include characters that allow them to withstand fire, such as thick bark, buds protected in dense vegetative tissue, and the ability to resprout from a variety of tissues (dormant buds or rhizomes, for example). On the other hand, the plant may be killed by the fire but its genetic offspring facilitated, such as in the case of seed release (serotiny), scarification of dormant seeds in the seed bank, or stimulation of flowering in surviving individuals (Kaufman 1990; Rowe 1983). Does the plant have any morphological adaptations that would make it more fire resistant or fire tolerant? Is the reproductive strategy primarily vegetative or by seed? If by seed, is postfire colonization from onsite or offsite seed sources? What about the fuel characteristics of the individual? Is it highly flammable? Does it have volatile compounds or abundant fine dead fuels that are easily ignited under the proper conditions?

# DATA SOURCES

Given these types of relationships, where can we get the information discussed? Basic information on endangered plants can be obtained from several sources. Species distribution and abundance can be found in the threatened

and endangered species lists maintained by your nearest U.S. Fish and Wildlife Ecological Services Field Office, the Nature Conservancy's Natural Heritage Data Base (NHDB) for your State, and publications such as the Threatened and Endangered Plant Field Guides (Atwood and others 1991; USDA Forest Service n.d.). These may also contain limited information on characteristics of the habitat and, in the case of the NHDB, information on threats.

Consult local and regional floras and herbaria for information on morphology. Little detailed information is available in published scientific literature. What is available can sometimes be found by consulting rare plant bibliographies, such as the one the Forest Service has prepared for Idaho (Moseley and others 1992). Information on fire effects could be obtained from the Fire Effects Information System Data Base (Fischer 1993), but the current system contains few rare plant taxa. Do not forget the wealth of information possessed by local botanists and ecologists.

Once available information has been assembled, assess the cumulative threats to that species not only on your site but throughout its range. Determine how critical your fire management action is to the continued survival of the species. It is important to remember, however, when making generalizations, that the resolution of your data affects the accuracy of your predictions. Much of this basic morphological/ecological information can be obtained from observations, which one can then expand to make inferences. However, it is essential to monitor these species over time to validate your assumptions (Owen and Rosentreter 1992). In other instances more specific data must be collected on the life history of the individual taxon or the characteristics of the fire regime. Remember that the burden of proof would likely increase with the rarity of or threats to a species.

## ADAPTIVE STRATEGY MODELS

We can further organize our information into a theoretical framework, as several authors recently have done by developing models of adaptive strategies. Existing information about the plant and its habitat—morphology, microhabitat, reproductive strategy—and the fire regime—fuels, fireline intensity, burn severity, and fire frequency—can be used to model the response of threatened and endangered species to fire.

Several authors have looked at differences in population-level ecological factors—including reproductive mode, competition, and population dynamics—and grouped species responses by their relative ability to compete in the postfire chaparral community (Keeley and others 1981; Moreno and Oechel 1991). Rowe (1983) keyed three vital attributes of the regeneration niche to fire activity, including mode of regeneration and reproduction (vegetative or seed), competitive relationships, and time scale of critical life history events as measured from the most recent fire. Using these relationships, he then categorized species from boreal habitats into five "modes of fire persistence" of plants (Rowe 1983; table 1): *invaders, evaders* and *avoiders, resisters,* and *endurers*. The species groupings facilitate predictions about their adaptations to various fire regimes. For example, *invaders* are highly dispersive pioneer species that are dependably present, though in variable quantity following fire, regardless of fire cycle length or intensity. In contrast, the *resisters* are species whose aboveground parts, at least in the adult stage, can resist or survive low-severity fires. Inferences can then be made about their relative adaptations to fire cycles of various length and differing moisture regimes (Rowe 1983; table 2).

This type of information may then be used to develop successional models. In the most recent example, Bradley and others (1992b) examined the relationship of major tree species to fire considering the plants' resistance to fire, their role in succession, and their special adaptations to fire. They then developed multipathway successional models for predicting the response of dominant tree species in 13 "fire groups" in Utah forests and woodlands. Finally, they summarized fire survival strategy, based on reproductive strategy (sprouting/seeding-colonizing abilities) and fire response.

## DISPLACED FIRE ADAPTATIONS

Characteristics that aid in to species survival under fire regimes may be adaptations to fire, other disturbances, biotic or soil stresses, or simply serendipitous (Rowe 1983). Thus, when evaluating plant adaptations to fire it is important to look not only for typical adaptations that evolved in response to fire but also to look for *displaced fire adaptations* that operate under the current conditions.

Take the interesting case of adaptations to aridity. In general for plants in Utah, the drier the geographic setting and soil type, the higher the endemism supported. A majority of rare plants in Utah (200 of the 240 taxa) are found in dry, desert environments (Shultz 1992). This becomes relevant if we relate arid adaptations (seed dormancy, tuber production, root crown development) to their possible adaptation to fire. It is true that many of these arid environments do not have a history of frequent or intense fires (McLaughlin and Bowers 1982), but adaptations to drought may by chance have created a fire-tolerant or fire-facilitated suite of adaptations that are critical to survival in today's often altered and largely unknown fire regimes.

## MESA VERDE EXAMPLE

To apply the method of analysis outlined earlier, we focus on the rare plants of Mesa Verde National Park, where we are conducting a fire history study. Although the populations are well surveyed, park managers lack specific information about fire adaptations to use in the prediction of the potential to survive large fires. The three rare taxa are the legumes, *Astragalus deterior* and *A. schmollae*, and *Hackelia gracilenta*. Each responds to fire in a unique manner—*A. deterior* lacks fire adaptations, but is found in a habitat unlikely to burn; *A. schmollae* may endure fire; *H. gracilenta* is facilitated by fire.

Mesa Verde National Park has a population of approximately 3,000 individuals of *Astragalus deterior*. It is a prostrate perennial plant with leaves emerging from a

shallow caudex or stem. It is shallow rooted, lacks a taproot, and is confined to growing in pockets of sandy soil overlaying limestone beach deposits that occur in bands on mesas and in a few drainages. There are no obvious fire adaptations in this species, an "avoider" in Rowe's terms. This specific habitat is xeric, occurring on the southern end of the mesa in a pinyon-juniper vegetation community. Observations by Mesa Verde Resource Management personnel show it persists in disturbed sites (M. Colyer, personal communication). There is no loess developed in this microsite and it lacks an overstory. From historic records, we know that fire often runs up the canyons in a northward direction. Although our preliminary data show a fire-return interval of on the average 75 years on the northern sector of Mesa Verde, the southern sector has a well-developed pinyon-juniper woodland that has not burned this century. We would expect a high-intensity fire here. However, the sparse fuels in the microhabitat of *A. deterior* will probably limit soil heating and prevent significant impacts to the population.

*Astragalus schmollae* has been monitored in permanent plots since 1980. It is locally widespread on only one mesa of Mesa Verde National Park, occurring as understory in dense pinyon-juniper woodlands in relatively deep loess soils. The mature pinyon-juniper woodland is an area of high fire risk. Fuel loading is extreme—clusters of trees have died, for example, from black root rot and other pathogens. We would expect a severe fire in the dense pinyon-juniper woodlands of the mesa tops. What is known about the plant's adaptations that might help us predict its survival when such fires occur? It is a perennial with a taproot. Its seeds germinate well in disturbed bare mineral or loose soils. This species expands through vegetative growth, creating individuals in clusters of many sizes. There is evidence that individuals may not resprout every year—suggesting that there is vegetative dormancy in the caudex area that could afford fire protection. Such an adaptation may have evolved in response to other conditions such as intermittent drought and serendipitously afford fire protection. Because of its deeply buried reproductive structures, this species may be able to survive a fire that causes some surface fuel reduction and soil heating. Fire may even create a suitable seedbed. In the terminology of Rowe (1983) this plant is an "endurer."

*Hackelia gracilenta* is a biennial of shorter stature than most stickweeds. It is locally abundant in disturbed habitats of Mesa Verde National Park, for example where trails have been maintained. After the 1989 fire near Rock Springs, this species expanded into disturbed habitats from wet drainages in the canyon. A large population was found near Mug House on Long Mesa in a wet year, but this species tends to be ephemeral, disappearing after 2 years from permanent monitoring plots (M. Colyer, personal communication). Thus, it is opportunistic, probably facilitated by recently burned habitats, and an "invader."

The Mesa Verde examples demonstrate the need to evaluate each rare species in the management area individually and in the context of its restricted microsite, as each may behave differently. *Astragalus schmollae* might survive a moderately severe fire because of its morphological adaptations, while *A. deterior* may be more protected within the pinyon-juniper zone because of its substrate restrictions. The stickweed may be facilitated by fire. More complete information on the population structure, proportion of the populations that actually occur within park boundaries, and the species adaptations to fire are needed.

## BUENOS AIRES EXAMPLES

Buenos Aires National Wildlife Refuge, located in southwestern Arizona, was established for the endangered masked bobwhite quail (*Colinus virginianus* var. *ridgwayi*). The refuge is burned to enhance quail habitat. Refuge goals also include enhancing biological diversity. Recently a cactus, *Coryphantha scheeri* var. *robustispina,* which is proposed for listing as a threatened species, was discovered in the refuge.

There was historic evidence that fire was a part of the ecosystem, but no detailed information was available on the natural fire frequency or intensity. Anecdotal evidence existed that some individuals had survived a fire. The refuge also had evidence that plants of low vigor seemed to occur in units that have not burned. With this information, the staff believed that the species had evolved with and was adapted to survive fire (S. Tolley, personal communication).

Refuge personnel consulted informally with U.S. Fish and Wildlife Ecological Services. Many areas had been mechanically manipulated for livestock forage, and an exotic grass, Lehman's lovegrass (*Eragrostis lehmanniana*), was introduced to control erosion. It has since spread extensively. Although the ecosystem was chiefly native grassland and had presumably adapted to fire, fuels had been altered with the introduction of the nonnative grass. Historically, the grassland was coarse grained and the cactus existed in open patches within the matrix of the scattered native bunchgrass-forb community. With the introduction of a nonnative grass with a more rhizomatous habit, portions of the habitat have become more fine grained with areas of continuous fuel (S. Rutman, personal communication). Little information is available on the alteration of fire behavior in this modified fuel regime. Greater fuel continuity and loading could possibly increase the frequency and fireline intensity of fires in those areas and the threat to the cacti's survival. The rare cacti inhabit both the altered and native (bunchgrass) habitat patches, but predominantly are located in areas of sparse fuels that would carry fire with difficulty. These fires would be of low fireline intensity (R. Madsen, personal communication).

In addition, an examination of the status of known populations showed that, although several existed throughout southern Arizona, the refuge population of about 40 individuals was the only population located on Federal lands. Further, with the potential for the Free-Trade Agreement and the associated development of the United States/Mexican border these other populations appear at greater risk in the future.

Ecological Services recommended measures to mitigate the possible effects of higher fireline intensities (and

possibly frequencies) in this system, at least until more information was gained about the effects of fire on this species or until fuels were reduced to more representative levels (S. Rutman, personal communication). In the interim, the refuge personnel are performing a complete census of their proposed burn areas and, if any cacti are found, are clearing fuels (by weed whacking) from around the immediate vicinity of the cactus. A detailed study of fire effects on *C. scheeri* var. *robustispina* will soon be under way. Although fire is beneficial for quail habitat, mitigation measures were still needed at this time to ensure the continued survival of this rare cactus. This example illustrates the need for compromise when determining fire strategies in areas known to contain endangered or threatened plants.

## A LOOK FORWARD

The current Endangered Species Act mandates a conservative approach to the management of T/E species. Fire may be used to enhance a rare plant habitat; however, seldom can we justify risking individual members of a population to benefit the species as a whole. A balance must be maintained in fire management decisions. With the recent examination of the Endangered Species Act we have begun to see greater emphasis on ecosystem management and preservation of natural processes. Vice President Al Gore and others have recently stated that we must preserve habitats and groups of species, rather than our current single species or "triage" approach to rare plant preservation. The Forest Service is identifying situations where a "coarse filter approach" (preserving habitat for most species) is more beneficial than a "fine filter approach," which protects a single species. If indeed it is judicious to try to protect clusters of rare species, we may need to focus our efforts on those habitats that promote endemism and support the largest numbers of rare plants. This comprehensive goal should apply directly to fire management.

To adequately predict the effects of fire on rare species, managers must know precisely the distribution of rare taxa within microhabitats. The habitat conditions immediately surrounding the rare population often are more important than the vegetation association. For example, a recent survey of T/E species in Arches and Canyonlands National Parks and Natural Bridges National Monument (Heil and Floyd 1993) revealed that three out of seven rare species occur in hanging-garden habitats within seeps. These microhabitats (seeps) have a relatively low fire potential, but are within a matrix of the larger pinyon-juniper plant community where the fire hazard is much greater.

A new focus on ecosystems may give managers an opportunity to take short-term risks with fire in relatively pristine areas such as wilderness where endangered species occur. But caution must accompany this opportunity. The notion of modern wilderness (or other natural areas) free of human impacts is likely just that—a notion—in most cases. The fire regimes to which species have adapted may bear little resemblance to the current one. Therefore, managers must still build a strong case for the use of fire even under the auspices of ecosystem management.

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# Appropriate Risks for Recreation in Wildlands

## Arnold Silverman

Thank you for inviting the Greater Yellowstone Coalition to participate in this forum. The Coalition, based in Bozeman, Montana, represents over 4,500 members in addition to about 90 local, regional, and national membership groups that support protecting the integrity of the Greater Yellowstone Ecosystem. We define the Greater Yellowstone Ecosystem as the area which has at its heart, Yellowstone and Grand Teton National Parks, surrounded by seven national forests, three national wildlife refuges, and other public and private lands in Montana, Wyoming, and Idaho—altogether 18 million acres of some of the most biologically diverse, unmatched country in the world. The Coalition works to ensure the long-term well-being of the natural and human resources of Greater Yellowstone, and continues to emphasize the need for healthy ecosystem management instead of management by political boundaries which bear little relationship to biological reality or problem-solving mechanisms.

During the Yellowstone fires of 1988, the Coalition was deluged with phone calls and media inquiries, including contacts from international press and letters from hundreds of people wanting to know what was happening in the park and why. It was a chaotic time, marked by often futile attempts to keep the long-term ecological perspective in the forefront, and to avoid biologically insupportable management by the masses of poorly informed people.

Since the fires, the Coalition has worked with national parks and forests in developing their wildland fire management plans. Until these plans are adopted, the agencies are under a policy of full suppression, even in wildernesses and the national parks. This policy of full suppression is at odds with scientific evidence regarding the ecological value of fire and its long history of shaping the Greater Yellowstone landscape. It is expensive, and in some cases involves a tremendous waste of resources. It represents an abrupt reversal of the policy of the past couple of decades, and is likely to aggravate public misconceptions about the role of fire in wildland settings, as well as agency philosophies regarding wildland fire. Agencies must adopt scientifically based prescribed natural fire plans. However, much more education needs to occur if we are to have broad public support for any wildland fire management plan which allows natural fires.

Earlier in this conference, you heard discussions about wilderness management in general, and fire policies within wilderness area and parks in particular. Now, we want to step back a moment to pull together some of that discussion in relation to recreational use in wildernesses and parks.

Let's return for a moment to the Wilderness Act of 1964. In that Act, Congress established a policy of designating wilderness lands "in order to assure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy and modify all areas within the United States and its possessions, leaving no lands designated for preservation and protection in their natural condition." Congress intended "to secure for the American people of present and future generations the benefits of an enduring resource of wilderness," lands intended to be used and enjoyed by the American people in ways that will leave them unimpaired for future use and enjoyment as wilderness: the ever-present, often incompatible mandate for unimpaired wildernesses and parks, to be enjoyed by all.

Wilderness is not simply a recreation resource, it is a resource of important natural, scientific and educational value. Humans seem to be propelled, by economic and other reasons, toward needing to manipulate resources and processes everywhere for some assumed better good - a tendency one writer described as a "tyrannical ambition of civilization to conquer every niche on the whole earth." As a geologist, let me point out that there are some landscapes humans are reluctant to exploit as energetically as the quote above implies. And other landscapes that, over time, are reclaimed by the natural forces of erosion and deposition to their undeveloped state. The pity is we learn so little collectively from these natural conditions.

Wilderness areas, however, provide us with the opportunity to allow natural processes to continue without gross human manipulation. The multi-agency Fire Management Policy Review Team, which issued its final report in May, 1989, acknowledged the important role of natural processes, and stated in its final report:

> ...(E)xtensive areas in which the achievement and maintenance of naturalness is a basic purpose are increasingly important to humankind. These areas are found primarily in national parks and wildernesses. They serve as invaluable scientific benchmarks; and the uniqueness imparted by their natural qualities is irreplaceable as a source of human inspiration and enjoyment.

In wilderness areas and national parks, the focus of wildland fire plans should be on allowing natural processes to the greatest extent possible. Natural processes do not necessarily equate to the most aesthetically pleasing conditions, particularly when events occur on a large scale, such as the Yellowstone fires of 1988.

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This does not make the value of such natural processes any less; it simply means we must do a better job of helping people understand that healthy, functioning ecosystems sometimes involve events that are not aesthetically pleasing. And that's fine. Ecosystems recover, and can be healthier for it. We do not need to, nor should we, feel obligated to manipulate and control and modify every niche of our ecosystems.

The goal behind wilderness areas and national parks is to provide undeveloped land retaining its primeval character and influence, with outstanding opportunities for solitude and undisturbed landscapes for recreation. There are many other places to recreate besides in wilderness, and many other ways. There are vast amounts of lands and commercial developments where consumers can be safe and comfortable. They can even drive through the parks and forests of the Yellowstone Ecosystem with minimal exposure to its backcountry wilderness, yet still enjoy a part of the uniqueness this country has to offer.

The wilderness resource, however, offers a very unusual experience. It is perhaps the last vestige where physical, emotional and spiritual limits can be challenged, expanded and nurtured. Everything about the experience is not safe, nor comfortable, nor easy. There is more risk simply because there is an emphasis on natural processes and one's place in a system where they are free to function. In truth, our ability to control these natural processes is limited. Fire ecologists tell us that there are major uncontrollable fires about every 200 to 300 years in the Greater Yellowstone Ecosystem. It is simply a matter of time, not whether such fires will happen.

One of the starkest examples of our limited ability to control fire is in the Coalition's backyard. The Absaroka-Beartooth Wilderness is a rugged, spectacular area encompassing almost one million acres along the northern border of Yellowstone Park. The main Boulder River corridor is a very narrow finger of non-wilderness lands, not much more than ½-mile wide between wilderness boundaries, snaking its way 25 miles through the national forest into the heart of the Absaroka-Beartooth Wilderness.

There is only one access road which dead-ends 50 miles from the town of Big Timber, population less than 2,000. Several popular church camps exist within this narrow finger of forested public and private lands. This wilderness area receives high hunting, fishing, hiking and other recreational uses. Fires on a large scale anywhere in this wilderness would be very difficult to control, including the main Boulder River corridor.

Perhaps we can learn from geologic events, which act in a setting of geologic time, how to educate and inform the public about natural events that are both cyclic and uncontrollable. I'm talking about events like earthquakes and volcanic eruptions, especially those associated with the West Coast subduction zone of the United States. The major quake cycle, or recurrence interval, along the San Andreas Fault is about 80 years, with smaller fault movements much more common. Major eruptive phases in the Cascades, Coast Ranges, and Yellowstone are measured in cycles of thousands to hundreds of thousands of years, with Mount St. Helens erupting only a decade ago.

And how do we deal with these events today? We monitor, we zone, we prepare for emergencies, but we do not, cannot, prevent; we cannot suppress; and we have decided against "protecting" people through evacuation and other means prior to the event. People are beginning to understand the risk—they are not asking for the hair-brained schemes of bureaucrats some years back to place nuclear devices (read "bombs") along the San Andreas Fault to release strain on the rock so as to prevent large quakes. Acceptance follows understanding, and is the key to fire control policy as well.

Our emphasis, then, must be on controlling human-caused fires, reducing risk, increasing educational efforts, improving users' abilities to handle natural occurrences—essentially, improving outdoor survival skills. Otherwise, we are in danger of losing our ecologically based policies, and our wilderness and national parks suffer.

Fire prevention starts with education and planning. It means developing a broader understanding of wilderness and national park areas—why they exist, how they're different, their scientific values, the way their management philosophies differ from those of other national forest lands or private lands. It means underscoring the impacts and risks that are created by developments within wildland areas or alongside wildernesses areas and national parks, much like we have begun to address the impacts and risks associated with developments on floodplains, fault zones and volcanic slopes.

Today, developed areas become zones of suppression, and the areas where natural processes are allowed to occur become smaller and smaller, squeezed between roads and cabins. Our wilderness resource suffers, and so do we as a people. Tomorrow, perhaps, we can establish a new accommodation that presents a healthy, and therefore sustainable, ecosystem.

# Availability of Resources and Funding

**Richard L. Stauber**

**Abstract**—The statement, "Availability of fire resources can be a serious constraint to conducting prescribed natural fire activities," illustrates some misunderstanding of prescribed fire programs. The availability of fire suppression resources should not be a "driving force" in our prescribed natural fire program, certainly no more than for any other prescribed fire activity. One of the fundamental precepts of prescribed burning is to have adequate resources to manage and suppress the prescribed burn as described in the plan. A second precept is that prescribed burning must be done at a time and in a manner so that it does not adversely affect our ability to respond to wildfire suppression activities.

Prior to beginning my remarks on the availability of fire resources and funding, I want to spend a minute explaining the National Interagency Fire Center (NIFC), formerly Boise Interagency Fire Center (BIFC). NIFC can be rather difficult to understand for those of us who work there, as well as for people in the field in the rest of the Country. NIFC is a location in Boise at the airport that is home to the national fire leadership for several Federal agencies. The number of people in the organizational levels varies from resource agency to resource agency. The Bureau of Land Management (BLM) provides land and facilities. The other agencies merely share in the cost as space users. BLM also houses fire personnel and resources to meet their own primary needs such as for smokejumpers and electronics computer system design (IAMS), as well as their equipment development organization.

The key decisions and actions that affect interagency fire suppression operations are the decisions made by the Multi-Agency Coordination (MAC) group. A director for each wildfire agency is a member of the group. As fire conditions, actions, and preparedness levels increase, additional members are added to the MAC group, such as a State Forester, General Services Administration representative, and Department of Defense liaison. I am the present chairman of this group, selected as the longest-tenured director at NIFC. It is our responsibility to assure that coordination is effective and to make essential decisions concerning the allocation of scarce national resources. Those decisions are based on the priorities and information provided to us from the geographic areas through our intelligence organization.

The National Interagency Coordination Center (NICC) turns the MAC group direction into action. The policies and procedures are well documented in the National Mobilization Guide. Woody Williams, Forest Service, and Skip Scott, BLM, jointly lead this organization. Our immediate customers are the geographic area coordination centers. Resource orders received from a geographic area in need are transmitted from NICC to another geographic area that can most appropriately supply the resources requested. NICC's main role is the movement of resources between geographic areas. With the exception of radio and other communication systems and infrared services, the location at Boise does not provide personnel or equipment to any major degree. Simply stated, our role is to "broker" fire resources from one part of the Country to another. And, under demonstrated emergency conditions, we can execute agreements with the United States military and Canada to extend the availability of fire resources beyond those available within the 50 States and the Federal wildfire community.

Agreements between and among the agencies provide for mutual support during fire and nonfire emergencies. In case of wildfire suppression actions, the agreement provides that each Federal agency pay for suppression support, and by agreement the Forest Service pays all bills to the States for support of Federal fire activities.

Emergencies other than fire such as flood, earthquake, or support to foreign countries are authorized by agreements, but the funding must be verified in advance.

Interagency cooperation and support begins at the local level, for prescribed fire as well as wildfire suppression. Interagency coordination centers at the local and geographic area are the key to this effort. In the case of prescribed fire, there is seldom sufficient demand or impact on local or geographic area resources to demand support through NICC.

## PROBLEM STATEMENT

The problem statement given to me in preparation for this conference stated in part: "Availability of fire resources can be a serious constraint to conducting prescribed natural fire activities." This statement illustrates some misunderstanding of prescribed fire programs. Availability of fire suppression resources should not be a "driving force" in our prescribed natural fire program, certainly no more than for any other prescribed burning activity.

One of the fundamental precepts of prescribed burning is to have adequate resources to manage and suppress the prescribed burn as described in the plan. A second precept is that prescribed burning must be done at a time and in a manner so that it does not adversely affect our ability to respond to wildfire suppression activities. I want to elaborate on these issues as they relate to prescribed natural fire.

## NATIONAL PERSPECTIVE

From a national perspective, all prescribed burning can, to some degree, be regulated by the National Fire Preparedness Plan. At the higher preparedness levels, administrative

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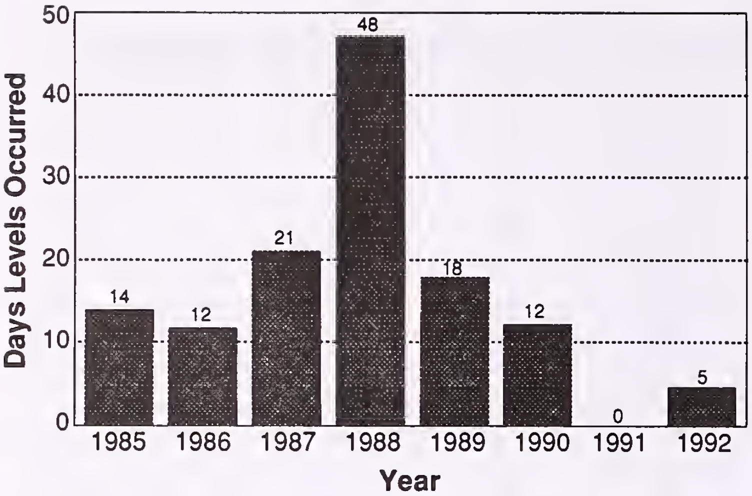


**Figure 1**—Number of days each year Preparedness Levels IV and V occurred, 1985 through 1992.

units with low-to-moderate fire danger and perhaps an excellent "burning window" will have restrictions placed on their burning so they can support the national fire suppression effort. These restrictions apply at Preparedness Levels IV and V. Figure 1 illustrates the number of days these levels have occurred. In 1992, that was five days. Appendix A is a description of the Preparedness Levels IV and V, providing interagency direction.

I can think of no activities since I arrived in Boise in 1989 in which Preparedness Levels IV and V were not equated directly to threat to life and property in a very dramatic way. Administrative units need to be proactive in their planning and risk assessments so they are not surprised by the need to respond to a national fire situation.

## PRESCRIBED NATURAL FIRE PLANNING

Prescribed natural fire presents some unique opportunities and challenges. Planning is quite specific and requires addressing several key issues that affect our ability to respond to wildfires. These include: fire projections using both expected and most severe weather scenarios; identification of maximum allowable perimeter; holding actions necessary to keep the fire within prescription; and a risk assessment.

It is imperative that these elements of the plan be carefully assessed using the latest technologies and planning tools, since they will determine the resources needed to undertake the project and potential impacts on fire suppression, and display the consequences of success and failure. Success or failure will not only be based on the environmental factors, but also on the social, political, and economic issues. In my opinion, these important factors have not always been adequately addressed in Prescribed Natural Fire Plans.

## POLICY REQUIREMENTS

One of the post-Yellowstone requirements for a prescribed natural fire is a risk assessment. This assessment among other things must focus on the impacts and conflicts with wildfire suppression activities. Such items as threat to life and property; adequacy of funds; resource availability for current and anticipated needs; fire intensity, prediction to remain within the maximum allowable perimeter; and current and predicted weather, including indications of long-term drought, are some of the issues that need to be addressed in this assessment. Success or failure of the prescribed natural fire rests on how well this assessment is made. From a wildfire suppression view, this is a paramount step in the development of the prescribed natural fire plan.

## PRESCRIBED FIRE MANAGERS

Successful prescribed fire managers are proven planners who are well versed in the many variables of prescribed burning. In addition, they respond in a proactive manner to changes. Having adequate resources on site and in reserve is one of the key elements to successful prescribed burn programs, whether they are in wilderness or elsewhere. Prescribed natural fires will require holding and mop up personnel from time to time and when the prescribed fire approaches the "maximum allowable perimeter."

The prescribed fire manager must ensure these resources and funding for them are available prior to conducting a prescribed natural fire. Prescribed burning that is being done based on the use or availability of fire suppression resources raises many questions in my mind and in most cases is not appropriate. Wildfire suppression activities, including initial attack programs, cannot be compromised for the benefit of the prescribed natural fire program.

## STAFFING AND FUNDING

The question, then, is how do we provide staffing and funding for a prescribed natural fire program. The answer is quite simple. In the same manner as for any other program, it is not realistic to think that a prescribed natural fire program can be conducted without staffing and funds. In my opinion we have not always adequately identified the funding and staffing needs to carry out a prescribed natural fire program in a proactive and professional manner and this needs to be done.

Prescribed natural fire has the potential to impact wildfire suppression activities, but with good planning and development of a "far sighted" risk assessment, a prescribed natural fire program can be implemented in a manner that will meet all of the agencies' needs and objectives.

# APPENDIX A—PREPAREDNESS LEVELS IV AND V

Description—Two or more geographic areas experiencing incidents requiring Type I Teams. Competition exists for resources between geographic areas. 450 crews or nine Type I Teams committed Nationally.

## 27.3.4 Preparedness Level IV:

| Management Direction/Consideration | Responsibility |
|---|---|
| a. Establish MAC Group at NIFC and conduct MAC Group Meetings at 0800 and 2000 MDT daily. | NIFC MAC Group. |
| b. Include State Forester and NFES Representatives on NIFC MAC Group. | NIFC MAC Group. |
| c. Suspend declaration of Prescribed Natural Fires, except those that are of no significance or risk. | Agency Administrators within Geographic Areas. |
| d. Establish IR Coordinator position at NIFC as appropriate. | NICC Coordinator. |
| e. Allocate/Pre-position National Resources. | NIFC MAC Group. |
| f. Train additional emergency firefighters as may be appropriate. | Agency Administrators within Geographic Areas. |
| g. Coordinate "off-site" training of emergency firefighters with Geographic Areas. | NIFC MAC Group Coordinator. |
| h. Encourage: (1) assignment of communications Frequency Managers and Aviation Specialists to all complex multiple incidents; (2) activation of MAC Group as may be appropriate. | Agency Administrators within Geographic Areas. |
| i. Geographic Areas provide NICC with fire priorities and other pertinent information at 0300 and 1700 daily. | Agency Administrators within Geographic Areas. |
| j. Implement Military Training Plan. Assemble Training Cadre for training Military. | NIFC MAC Group Coordinator. |
| k. OAS and FS Aviation contract, award, and inspect additional CWN Type 1 and 2 helicopters. | National Aviation Officer and Director of OAS. |

## 27.3.5 Preparedness Level V:

Description—Several Geographic Areas are experiencing major incidents which have the potential to exhaust all Agency Fire Resources. 625 crews committed Nationally.

| Management Direction/Consideration | Responsibility |
|---|---|
| a. Continue with Planning Level IV activities. | NIFC MAC Group Coordinator. |
| b. Request Military and Canadian Liaison for NIFC MAC Group. | NIFC MAC Group Coordinator. |
| c. Add Coordinator position at NIFC to coordinate Military mobilizations. | NIFC MAC Group Coordinator. |
| d. Curtail all new Management Ignited Prescribed Fires. | Agency Administrators within Geographic Areas. |

# Availability of Fire Resources and Funding for Prescribed Natural Fire Programs in the National Park Service

**Stephen J. Botti**
**Howard T. Nichols**

**Abstract**—Prescribed natural fire programs in the National Park Service have changed dramatically following the 1988 Yellowstone fires. The area burned per year has declined by 94 percent even though the area within prescribed natural fire zones has increased. The program has been constrained by conservative prescriptions, preparedness planning, and changes in funding availability. To reestablish ecologically significant programs, alternative strategies for funding, prescriptions, and resource availability need to be considered.

The modern era of prescribed fire management in the National Park Service (NPS) began after the recommendations from the Leopold Report on Wildlife Management in the National Parks (Leopold and others 1963) were incorporated into NPS management policies in 1968. These new policies encouraged large, natural-area parks to utilize fire as a resource management tool to restore and maintain natural ecosystems. The policy stated:

> The presence or absence of natural fire within a given habitat is recognized as one of the ecological factors contributing to the perpetuation of plants and animals to that habitat.
>
> Fires in vegetation resulting from natural causes are recognized as natural phenomena and may be allowed to run their course when such burning can be contained within predetermined fire management units and when such burning will contribute to the accomplishment of approved vegetation and/or wildland management objectives.
>
> Prescribed burning to achieve approved vegetation and/or wildland objectives may be employed as a substitute for natural fire. [USDI National Park Service 1968].

Although prescribed natural fire management began in the western parks in 1968 at Sequoia and Kings Canyon National Parks, the NPS program evolved from an experimental to an operational phase in 1974, when 125 fires burned 21,566 acres (8,626 hectares). Prescribed natural fire management soon was adopted by most large western parks and some small ones, and by 1981, 182 fires were allowed to burn 56,227 acres (22,490 hectares). These fires were generally allowed to burn without specific weather, fuel moisture, or size limitations as long as they presented no threat to visitor safety, the smoke presented no health hazard, and they did not threaten to escape from designated zones. These fires were routinely monitored by resource management and fire personnel, and operational costs other than salaries were funded by emergency presuppression accounts. The program remained highly active until 1988, as shown on table 1.

Prescribed natural fire (PNF) management in the National Park Service changed dramatically (fig. 1) after the Yellowstone fires of 1988, some of which began as PNF's and were later suppressed. An interagency team was established to review the adequacy of existing prescribed natural fire policy and programs. In following the recommendations of that team, Federal agencies directed that PNF programs should be restored, but with significantly

**Table 1**—Prescribed natural fires, lands managed by National Park Service, 1968-92

| Year | Number of fires | Hectares burned |
|---|---|---|
| 1968 | 3 | 3.20 |
| 1969 | 1 | 0.10 |
| 1970 | 24 | 197.80 |
| 1971 | 46 | 4,609.90 |
| 1972 | 53 | 1,539.80 |
| 1973 | 93 | 6,757.60 |
| 1974 | 129 | 10,277.10 |
| 1975 | 89 | 798.00 |
| 1976 | 116 | 1,352.90 |
| 1977 | 95 | 5,235.10 |
| 1978 | 158 | 2,219.60 |
| 1979 | 82 | 5,759.60 |
| 1980 | 125 | 6,265.70 |
| 1981 | 181 | 22,468.90 |
| 1982 | 89 | 2,805.60 |
| 1983 | 94 | 4,061.60 |
| 1984 | 193 | 15,518.20 |
| 1985 | 164 | 18,358.30 |
| 1986 | 138 | 19,548.20 |
| 1987 | 180 | 6,024.60 |
| 1988 | 150 | 23,583.20 |
| 1989 | 0 | 0.00 |
| 1990 | 32 | 1,218.30 |
| 1991 | 51 | 907.60 |
| 1992 | 111 | 741.40 |
| Total | 2,397 | 160,253.30 |

In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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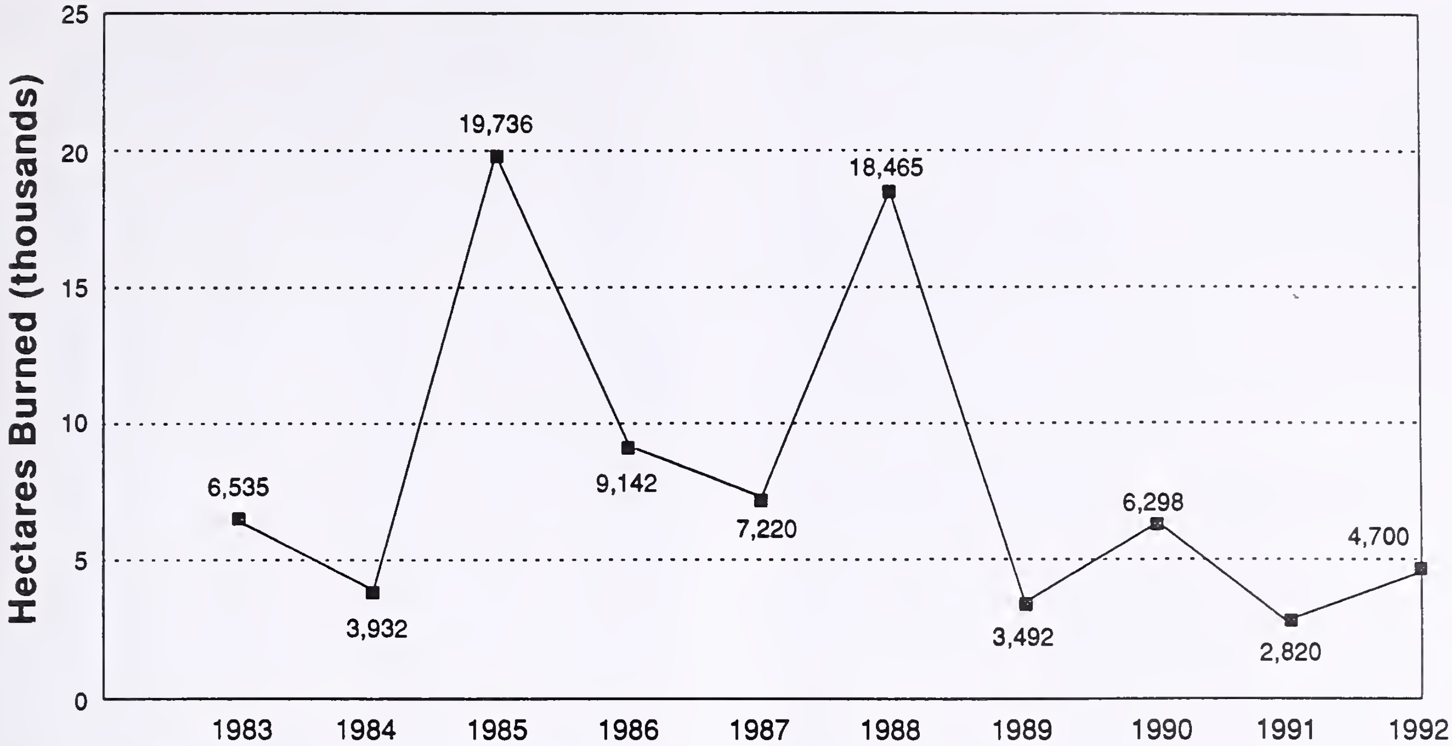


Figure 1—Total prescribed fire in prescribed natural fire units managed by the National Park Service, 1983-92 (excludes Big Cypress National Preserve).

greater funding, operational, and prescriptive constraints than in the pre-1988 program. In Special Directive 89-7, the Director of the NPS required that the following conditions be met (following the interagency team recommendations) before PNF programs could be resumed:

Agencies develop regional and national contingency plans to curtail or constrain prescribed natural fires under extreme conditions.

Agencies implement a daily certification process verifying that adequate resources are available to assure prescribed natural fires will remain within prescription given certain conditions and, if not, to declare these fires wildfires and to initiate suppression action.

The Superintendents, or their designated acting, shall certify on the Fire Situation Analysis that the prescribed natural fire is within prescription and is expected to remain so through the next 24-hour period with the resources and funds available or declare it a wildfire and to initiate suppression action.

The agencies will review the funding methods for prescribed fire and fire protection programs to improve interagency effectiveness and minimize emergency fund transfers and need for supplemental appropriations.

The 1990 Wildland Fire Management Guideline for the NPS (NPS-18) further specified that the information required for daily certification be collected according to a predetermined monitoring schedule specified in the park fire management plan. The monitoring schedule "will be based on the number and kind of values at risk...and the time the fire is projected to reach a value at risk" (USDI National Park Service 1990). To meet this requirement, the NPS base-funded teams of monitors in PNF parks and trained collateral duty monitors to supplement the program during periods of high activity. At present, the NPS base-funds 43 monitors at 13 parks, at an annual cost of $381,000.

The number of parks with PNF programs has declined from 26 to 17 (35 percent) between 1988 and 1992, but it appears likely that five of the remaining nine programs eventually will be restored. The number of hectares managed under PNF programs has actually increased from 3,450,000 to 3,689,000 in the same time period, and another 560,000 may be added in the next 2 years. Restoring the remaining programs would require employing additional base-funded monitors, further increasing monitoring costs.

The number and location of monitors is determined by an analysis of the normal-year PNF workload and complexity in each park. The normal year is defined as the year with the third highest number of acres burned in the last 10 years. When a park experiences a monitoring need exceeding its internal capability, that need is filled by dispatching monitors from other parks. By maintaining a mobile monitoring capability, the NPS achieves a Most Efficient Level (MEL) of operation by incorporating the same philosophy used in managing interagency suppression resources. The MEL normal-year planning reduces overall program cost because each park does not staff for the greatest potential workload and complexity. Although staffing needs are predictable, operational support costs, including premium pay, aircraft, and travel charges required to monitor PNF's are unpredictable due to the great variation in the number, location, impacts, and threats to values at risk from PNF's in a given year. In addition, planned actions to hold a PNF within prescription, such as constructing a fireline or burning out a boundary, also must be funded from nonemergency project funds.

In response to the Fire Management Policy Review Team's recommendations, Congress established the Interior Department's Fire Protection and Emergency Firefighting funds in 1990. These no-year funds are designed to fully

fund bureau fire programs at the MEL. Fire Protection funds are programmed at the beginning of each fiscal year, and emergency funds are not programmed, but are utilized as the need arises. The rules for these funds specify that agencies use only programmed, project funds to manage and monitor prescribed natural fires and management-ignited prescribed fires (prescribed burns), and that the emergency fund be restricted to wildfire suppression, emergency wildfire rehabilitation, and emergency presuppression activities. All prescribed fire management is treated as a normal, programmed activity that can be budgeted for up-front, without any need for access to emergency funds.

As a result of the new prescription, monitoring, and contingency planning program constraints, the NPS prescribed natural fire program remains far below the activity level experienced in the 10 years prior to the Yellowstone fires (table 1). The area burned per year between 1989 and 1992 has declined 94 percent compared to the immediate pre-Yellowstone period 1983-87, even though the area within PNF zones has increased by 7 percent. The increasing conservatism of PNF management is further demonstrated by the fact that during the 1983-87 period the average size of a PNF was 206 acres (82 hectares), compared to 37 acres (15 hectares) between 1989 and 1992. Perhaps more significantly, the average size has steadily declined from 95 acres (38 hectares) in 1990 to 44 acres (17.6 hectares) in 1991 to 17 acres (6.8 hectares) in 1992.

The continuation of a major drought cycle in the western States between 1988 and 1992 has also been a major factor in constraining PNF programs. The 1989 policy revisions definitely accomplished one stated goal, which was to force PNF programs to utilize more conservative prescriptions during severe drought years. These prescriptions, together with the understandable reluctance of managers to risk another major escaped PNF after Yellowstone, contributed to the dramatic program decline since 1988. Since recent research from the Sierra Nevada (Tom Swetnam, personal communication) suggests that prehistoric drought cycles produced widespread and intense fires, the severe program constraints during the recent drought may have produced a more pronounced disruption of natural fire regimes than would have been the case in a "normal" fire year. The return to normal or above-normal precipitation in all of the PNF parks may establish the 1993 fire season as the first opportunity since the policy revisions in 1989 to fully test the effect of the revisions on "normal year" operational and funding requirements.

Management-ignited prescribed fire also expanded rapidly in the 1970's and 1980's. Many of these burns are/were conducted in wilderness areas, which is permitted under NPS policy (USDI National Park Service 1990). These burns are conducted to remove hazardous fuels and to maintain the natural influence of fire by replacing suppressed lighting-caused fires. In contrast to the PNF program, the management-ignited prescribed fire program has continued to expand post-1988 (table 2).

It would be a mistake, however, to interpret these data as indicating that management-ignited prescribed fire has been used as a substitute for prescribed natural fire. Most of the increase in area prescribed-burned has occurred in Big Cypress National Preserve in south Florida. With Big Cypress excluded, the average annual area prescribed-burned post-1988 is 16,602 acres (6,640 hectares) compared to 16,140 acres (6,456 hectares) pre-1988. The 25 park units that permitted PNF prior to 1988 (excluding Big Cypress) prescribed-burned an average of 12,596 acres (5,038 hectares) per year between 1983 and 1987, and only 8,977 acres (3,590 hectares) between 1989 and 1992. These 25 parks recorded an annual average of 13,793 acres (5,517 hectares) burned by PNF between 1983 and 1987, compared to an annual average of only 1,793 acres (717 hectares) between 1989 and 1992. Thus the total influence of prescribed natural fire within these fire-dependent ecosystems has been reduced by 87 percent, and management-ignited prescribed fire has been reduced by 29 percent (tables 3 and 4).

**Table 2**—Management-ignited prescribed fires, lands managed by National Park Service, 1968-92

| Year | Number of fires | Hectares burned |
|---|---|---|
| 1968 | 1 | 320.00 |
| 1969 | 3 | 2,536.00 |
| 1970 | 9 | 785.60 |
| 1971 | 11 | 488.00 |
| 1972 | 8 | 975.20 |
| 1973 | 4 | 107.20 |
| 1974 | 9 | 333.20 |
| 1975 | 52 | 5,019.20 |
| 1976 | 50 | 3,345.20 |
| 1977 | 26 | 2,859.70 |
| 1978 | 29 | 3,809.70 |
| 1979 | 93 | 5,369.90 |
| 1980 | 101 | 9,896.10 |
| 1981 | 131 | 17,612.20 |
| 1982 | 117 | 6,521.00 |
| 1983 | 107 | 7,633.50 |
| 1984 | 132 | 7,159.40 |
| 1985 | 139 | 14,938.20 |
| 1986 | 120 | 14,579.10 |
| 1987 | 115 | 11,599.80 |
| 1988 | 98 | 8,540.30 |
| 1989 | 154 | 22,083.30 |
| 1990 | 165 | 33,169.70 |
| 1991 | 136 | 22,625.90 |
| 1992 | 169 | 24,817.40 |
| Total | 1,979 | 227,124.80 |

## POST-1988 PNF CONSTRAINTS

The 1988 Fire Management Policy Review Team was correct in stating that prescribed natural fires cannot be allowed to burn without reasonable constraints. There are no parks and wilderness areas in the lower United States large enough or isolated enough to sustain totally natural fire regimes. The Yellowstone fires demonstrated that some fire regimes operate on a true "landscape" or "ecosystem" basis that cannot be sustained at an acceptable level of risk to external values in the modern world. Park managers are then left with the difficult decision of finding a balance between minimizing human interference with wilderness fires and achieving other park management goals, including the protection of life and property and providing for visitor

**Table 3**—Management-ignited prescribed fires in prescribed natural fire units, National Park Service, 1983-87, 1989-92 (1988 omitted due to reduction in prescribed burning capability)

| Park unit | 1983-87 Number of fires | 1983-87 Hectares burned | 1989-92 Number of fires | 1989-92 Hectares burned |
|---|---|---|---|---|
| Bandelier | 20 | 113 | 20 | 616 |
| Big Bend | 7 | 10 | 1 | 2 |
| Big Cypress | 128 | 21,868 | 67 | 76,132 |
| Buffalo | 13 | 114 | 28 | 65 |
| Carlsbad Caverns | 6 | 32 | 11 | 70 |
| Chiricahua | 5 | 91 | 7 | 56 |
| Crater Lake | 6 | 100 | 0 | 0 |
| Death Valley | 0 | 0 | 0 | 0 |
| Dinosaur | 2 | 576 | 1 | 24 |
| Everglades | 61 | 19,142 | 41 | 8,928 |
| Glacier | 0 | 0 | 2 | 33 |
| Grand Canyon | 19 | 1,259 | 34 | 1,424 |
| Grand Teton | 0 | 0 | 0 | 0 |
| Isle Royale | 0 | 0 | 0 | 0 |
| Joshua Tree | 3 | 5 | 2 | 10 |
| Lake Mead | 0 | 0 | 0 | 0 |
| North Cascades | 0 | 0 | 1 | 19 |
| Olympic | 0 | 0 | 0 | 0 |
| Rocky Mountain | 0 | 0 | 3 | 2 |
| Saguaro | 3 | 42 | 0 | 0 |
| Sequoia and Kings Canyon | 17 | 1,369 | 34 | 1,464 |
| Voyageurs | 0 | 0 | 4 | 292 |
| Wupatki | 0 | 0 | 0 | 0 |
| Yellowstone | 0 | 0 | 1 | 192 |
| Yosemite | 15 | 2,246 | 31 | 982 |
| Zion | 3 | 6 | 6 | 186 |
| Total | 308 | 46,973 | 294 | 90,497 |
| Avg/year | 61.6 | 9,395 | 73.5 | 22,624 |

use and enjoyment. In balancing the political, economic, and social constraints necessary to manage prescribed natural fires with resource management objectives, the fundamental questions become:

- How much deviation from natural conditions can be tolerated and still permit agencies to assert that PNF programs are maintaining natural vegetative communities and related ecosystems?

- Within existing PNF zones, what are the consequences of significant long-term deviation from natural fire regimes on fuel loadings, fire behavior, and vegetative community structure?

- To what extent does suppression of natural fires degrade wilderness ecosystems, and therefore all values, both biological and social, derived from them?

## Prescription Constraints

Current NPS policy requires that prescribed natural fires have measurable prescriptions, at least one of which must be a drought indicator. Other typical prescription parameters include the number of PNF's that can burn at one time, the maximum number of acres that can burn in a given year, the maximum size of individual fires, and threshold criteria for smoke impacts. For most programs, these criteria are more restrictive now than prior to 1988. Although there is little doubt that more strict prescriptions have reduced risks from PNF's in the short run, the long-term impact of such restrictions on the original program goal of restoring the historic/ecologic influence of natural fire in a cost-effective manner is difficult to assess. Managers must make this assessment, however, to answer the three questions listed earlier.

The effects of prescription constraints on natural fire regimes may be far greater than the number of PNF's suppressed indicate. Statistics demonstrating that 30 to 40 PNF's are allowed to burn each year in a park may mask the fact that a large percentage of the key ecologically significant events are being eliminated or highly modified. Of the 194 PNF's allowed to burn between 1989 and 1992, only five eventually were suppressed (2.5 percent) (fig. 2). Before they were suppressed, however, these five fires accounted for 72 percent of the area burned by all PNF's during this time period. It is likely that continued major human disruptions of the natural burning patterns and intensities in wilderness areas will eventually change fuel loadings and the composition of vegetative communities. It is only the rate of change that is uncertain, and at present parks do not have effective monitoring systems in place to measure this change.

**Table 4**—Prescribed natural fires in prescribed natural fire units, National Park Service, 1983-92 (1988 omitted due to moratorium)

| Park unit | 1983-87 Number of fires | 1983-87 Hectares burned | 1989-92 Number of fires | 1989-92 Hectares burned |
|---|---|---|---|---|
| Bandelier | 4 | 14 | 1 | 13 |
| Big Bend | 15 | 182 | 0 | 0 |
| Big Cypress | 35 | 3,892 | 0 | 0 |
| Buffalo | 1 | 17 | 0 | 0 |
| Carlsbad Caverns | 8 | 750 | 3 | 1 |
| Chiricahua | 0 | 0 | 0 | 0 |
| Crater Lake | 16 | 5 | 0 | 0 |
| Death Valley | 0 | 0 | 0 | 0 |
| Dinosaur | 106 | 1,318 | 37 | 6 |
| Everglades | 69 | 14,005 | 3 | 50 |
| Glacier | 2 | 1 | 4 | 5 |
| Grand Canyon | 53 | 538 | 2 | 4 |
| Grand Teton | 1 | 1 | 7 | 1 |
| Isle Royale | 1 | 1 | 0 | 0 |
| Joshua Tree | 2 | 8 | 0 | 0 |
| Lake Mead | 0 | 0 | 0 | 0 |
| North Cascades | 23 | 64 | 2 | 1 |
| Olympic | 1 | 71 | 0 | 0 |
| Rocky Mountain | 0 | 0 | 1 | 0 |
| Saguaro | 7 | 6 | 5 | 35 |
| Sequoia and Kings Canyon | 111 | 3,146 | 38 | 1,903 |
| Voyageurs | 0 | 0 | 1 | 17 |
| Wupatki | 2 | 2 | 0 | 0 |
| Yellowstone | 58 | 396 | 16 | 1 |
| Yosemite | 97 | 6,952 | 73 | 833 |
| Zion | 23 | 112 | 0 | 0 |
| Total | 635 | 31,481 | 193 | 2,870 |
| Avg/year | 127 | 6,296 | 48 | 717 |

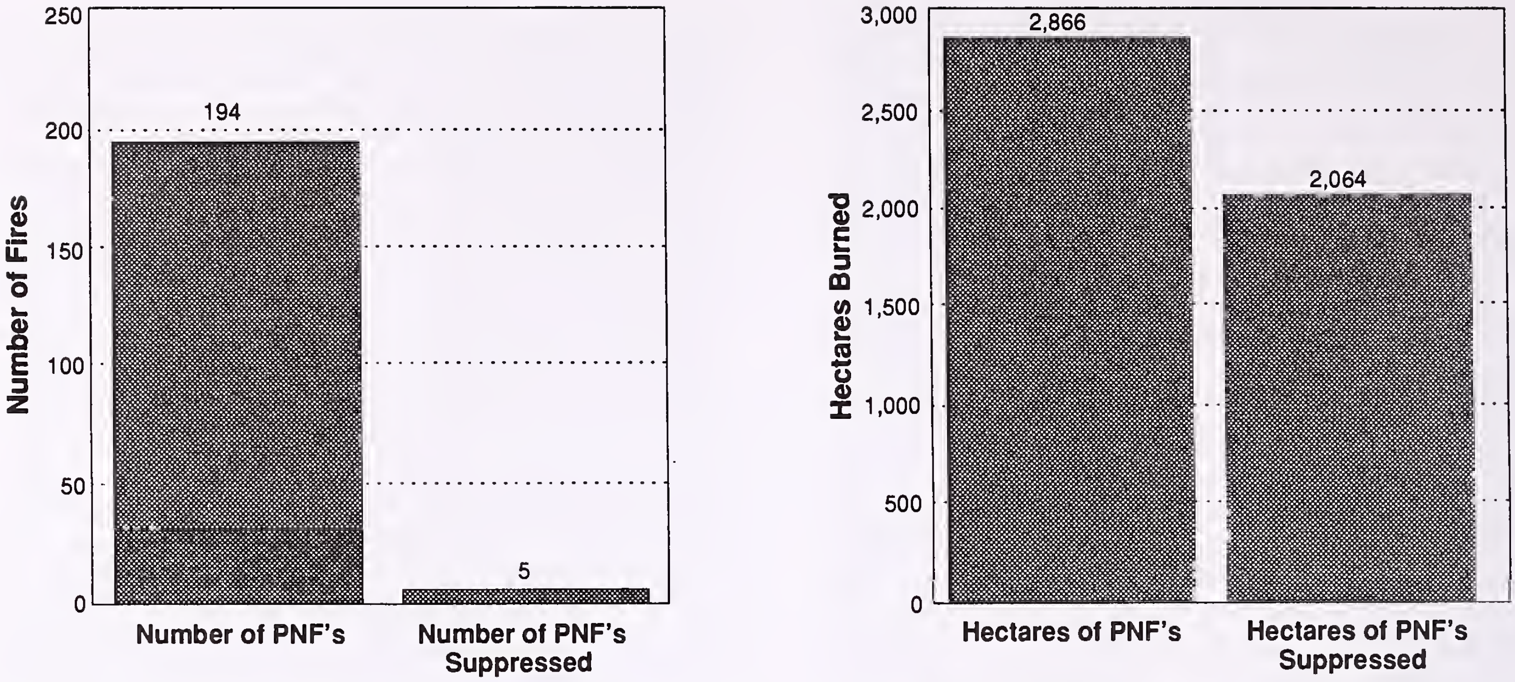


**Figure 2**—Prescribed natural fires and those suppressed, 1989-92, for units managed by the National Park Service.

## Preparedness Plans

The final report of the Fire Management Policy Review Team recommended that, in deciding whether or not to allow natural ignitions to burn as prescribed fires, agencies give:

> Appropriate consideration to the national and regional fire situation, including the numbers of fires and amount of available resources to suppress them (USDA, USDI 1989).

It further recommended that

> Agencies will cooperatively develop regional and national contingency plans and procedures and provide the appropriate program monitoring and direction, including curtailment of prescribed fire activities when necessary because of competition for national and regional fire suppression resources (USDA, USDI 1989).

In response, the NPS and other agencies developed national and regional interagency preparedness plans. These plans define actions that will be taken to increase wildfire preparedness in response to increasing wildfire danger, number of project wildfires, and competition for firefighting resources. At planning levels IV and V, when many project wildfires are occurring and competition for resources is intense, no new PNF's are permitted, except for those of no significance or risk.

Obviously, the definition of "no significance or risk" is critical in determining how many potential PNF's will be suppressed, and thus the disruptive impact of this constraint on PNF program goals and objectives. The term is usually defined to mean only those PNF's that will be confined at small size by natural barriers, but is clearly open to interpretation.

In a normal year, many PNF's at parks such as Yellowstone, Yosemite, Sequoia and Kings Canyon, Glacier, and Grand Teton would not meet a size criterion for no significance due to extensive areas of contiguous fuels within the PNF zone. If staffing requirements are used as a criteria, is a PNF, regardless of size, not significant if it can be managed solely by in-house or agency personnel without any reliance on external resources, even though these personnel would not be available for wildfire dispatch? This question still remains to be answered by interagency regional oversight groups.

In conjunction with project planning documents such as the NPS's Fire Situation Analysis, preparedness plans have required managers to quantify the impacts of PNF's on wildfire suppression capability, and set relative priorities for utilizing existing resources for either suppression or PNF preparedness, including actual or planned (contingency) actions. In general, these contingency reserve resources are defined as "those forces...identified by name in the prescribed burn plan or prescribed natural fire plan for meeting the contingency actions should the fire exceed prescription parameters and/or holding capabilities" (Albright 1991).

Direct competition for resources occurs because park managers are required to certify "that the prescribed natural fire is within prescription and is expected to remain so through the next 24-hour period with the resources and funds available or declare it a wildfire and to initiate suppression action" (Lujan 1989).

The dual emphasis of reserving resources for holding actions and suppression actions has further complicated preparedness planning. As now applied, contingency reserves are maintained for planned holding actions to keep a PNF within prescription and for resources needed for suppression actions if the PNF exceeds prescription. In general, these resources are base-funded wildfire initial attack personnel and equipment, not PNF-funded resources.

By establishing the priority of wildfire suppression operations over PNF operations, preparedness planning has decreased the resources available for PNF management and forced managers to suppress many PNF's that were

otherwise within prescription. If the purpose of preparedness plans is to avoid committing suppression resources to PNF management when those resources are needed for wildfire emergencies, the result may be a Catch-22. By triggering suppression of PNF's during resource shortages, the system is creating further shortages at the worst possible time.

Most PNF's start in midsummer and become large by late summer or early fall, during the critical western fire season. During high preparedness levels, managers must predict whether new starts will remain at "no risk" for holding or suppression actions for the entire course of the fire, or at least during that portion of the fire season with high preparedness levels.

Since 1989 at least 14 potential or actual PNF's are known to have been suppressed because of preparedness plans. In some cases, park managers have been reluctant to let PNF's become large even at the lower preparedness levels in order to avoid the risk of a major suppression action later when resource competition may be critical.

Since it is common for these fires to burn for 1 to 3 months, preparedness levels may have changed by the time the PNF actually requires resources. The system, however, encourages a conservative analysis based on the presumption that resource competition will exist when the fire becomes large.

Conservative prescription and management constraints as a result of the 1989-92 drought years, including limitations on size of individual PNF's, the number allowed to burn at one time, and a temporary reduction on the area within PNF zones, may have masked the potential effect of preparedness planning on resource availability for PNF management. Although the recent drought period created a large demand for resources to suppress a large number of project wildfires, there is some evidence from Yosemite and Sequoia and Kings Canyon Parks that thunderstorm activity within PNF zones may have decreased in the 1976-77 and 1987-92 drought periods. In the postdrought, "normal" year period, the combined effect of increased lightning activity and expansion of PNF zones into lower, more extensively vegetated areas may result in a larger number of moderate- to large-sized PNF's. These PNF's may require more contingency and management resources than have the smaller PNF's in the past four years. Therefore, 1993 may be the first test of the significance of preparedness plans on PNF programs.

Few will argue with the premise that the first priority for suppression resources is to protect life and property. The conflict in preparedness planning is whether or not fire suppression resources can be shared with PNF programs during the overlapping wildfire and PNF seasons. If the answer is no, the resources cannot be shared, then parks may seek to develop parallel but separate wildfire and prescribed fire organizations in order to maintain ecologically significant PNF programs. Prescribed fire resources would remain PNF-dedicated and unavailable for wildfire suppression, except for extreme emergencies. This concept is already being utilized with PNF fire monitoring personnel, but has not been applied to holding forces.

To be successful, this strategy would require a large number of crews to be on standby at the park or regional level for the infrequent holding action on a large PNF. Recruiting and mobilizing these personnel would significantly increase PNF program funding requirements. These personnel could, however, serve a dual purpose by reducing the backlog of hazard fuel reduction projects, and could be funded in part by hazard fuel reduction project funds.

The concept of separating suppression and PNF resources will doubtless provide much controversy. The fact that it is suggested at all is indicative of the tension within the fire management community over how to utilize scarce resources to serve two conflicting mandates. The NPS must serve as a full and reliable partner for interagency wildfire suppression response, and at the same time remain faithful to its unique land management mission of preserving the natural biosphere in parks for the enjoyment of future generations.

## Funding Constraints

In 1990 the General Accounting Office issued a report on how successful Federal agencies had been in reimplementing prescribed fire programs following the Fire Policy Review Team recommendations (GAO 1990). That report stated:

> The Review Team's report endorsed the practice of allowing fire to play its natural role in wildland ecosystems. The report stated that in parks and wildernesses where fire has been a historic component of the environment, the continuation of its influence is critical. The report also stated that attempts to exclude fire from these lands could lead to major unnatural changes in vegetation and wildfire and contribute to uncontrollable wildfires as the result of an accumulation of fuels.

The GAO report further stated:

> The funds available to specifically operate a prescribed fire program have fallen short of the amount managers say they need. Without adequate funds, fire and wilderness managers committed to the ecological benefits of fire often lack the resources required to effectively operate prescribed fire programs.

The Fire Management Policy Review Team recommended that,

> Agencies review funding methods for prescribed fire programs and fire suppression to improve interagency program effectiveness.

The effectiveness of prescribed natural fire programs is not being improved by the current system of requiring that unpredictable natural fire events be managed entirely within the constraints of a fixed budget within program management. The chances are great that in normal years, and almost certainly in extraordinary years, many prescribed natural fires that would have had a widespread and critical impact on the ecological health of natural ecosystems will be suppressed due to lack of management funds.

A review of program statistics from 1978 through 1987 shows the potential problems associated with the current management strategy. The number of prescribed natural fires varied from 82 to 193 and the area burned varied from 5,549 acres (2,220 hectares) to 56,172 acres (22,469 hectares). If the NPS budgets for a normal-year (third highest) target of 169 fires and 49,000 acres (19,600 hectares), it will have a large budget surplus in many years, and in

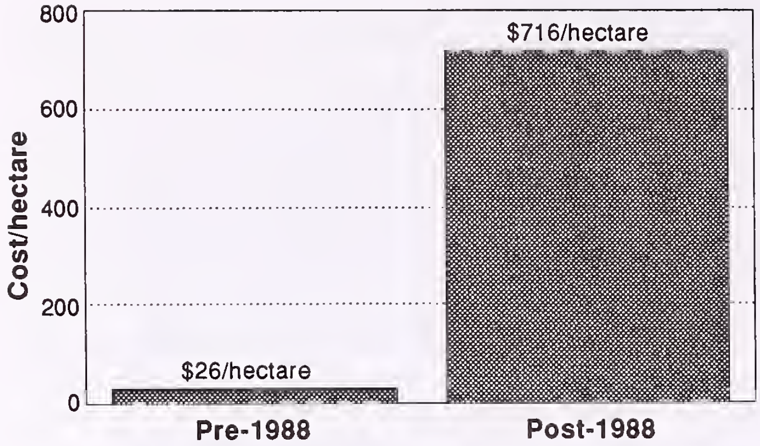


**Figure 3**—Cost per hectare for prescribed natural fire management by the National Park Service, pre-1988 and post-1988.

the two most active years, which may also be the most ecologically significant within the fire regime, up to 20 fires (probably the largest and most ecologically significant ones) may be suppressed. If the NPS budgets for the pre-1988 peak scenario of 193 fires and 56,000 acres (22,400 hectares), there is still no guarantee that it will have enough funds to cover all management and monitoring actions, because the location and management problems associated with each prescribed natural fire are unique. Such a strategy is likely to result in a very large surplus in most years, however.

In 1992 the NPS spent $530,908 to manage 111 prescribed natural fires that burned 1,853 acres (741 hectares) ($286/acre or $716/hectare) (fig. 3). This is about the same amount spent for pre-1988 normal-year monitoring and management at $10/acre ($26/hectare) ($500,000 for 140 fires burning 49,000 acres [19,600 hectares]). Is this 2,760 percent increase in cost per acre a reasonable and justifiable consequence of implementing the Policy Review Team recommendations? It might be justifiable if it would prevent a recurrence of the resource impacts and costs associated with a Yellowstone-type fire situation, while maintaining ecologically significant PNF programs. The increase in cost per acre has affected all PNF parks, however, not just those at high risk for PNF escape due to crown-fire regimes.

Excluding the Alaska parks, which easily can sustain crown-fire regimes in their vast wilderness areas, 83 percent of PNF's prior to 1988 were in parks with fire regimes largely characterized by low- to moderate-intensity surface fires. The cost effectiveness of such a dramatic cost-per-acre increase in these parks is debatable. For example, about 15 of the 684 PNF's in Yosemite and Sequoia and Kings Canyon National Parks between 1968 and 1987 were suppressed with partial containment actions. Most of these actions were taken to reduce unacceptable smoke impacts, not because the PNF's had escaped from designated zones. Since none of these suppression actions required a commitment of more than four crews, there is no evidence that PNF's in surface-fire regimes are likely to require hundreds of crews during severe wildfire periods. In 1987, a 3,500-acre (1,400-hectare) PNF burned in Yosemite throughout the entire duration of the 147,000-acre (58,800-hectare) project wildfire, the Stanislaus Complex, without requiring any management action. The fire was within 5 miles of the Stanislaus Complex, but was in a different vegetation type characterized by a fire regime of low- to moderate-intensity surface fires. Under the post-1988 prescription and preparedness planning constraints, this PNF might have been suppressed.

It is possible that the per-acre cost in 1992 may have been unusually high due to the combination of several constraining factors: the conservative monitoring and management requirements due to drought conditions, the more intensive monitoring requirements for post-1988 PNF's, and the small number of acres burned (fewer than in any year since 1970). Nevertheless, given the current monitoring requirements, it is doubtful if current normal-year monitoring could approach the pre-1988 $10/acre ($26/hectare) figure. Managing a pre-1988 normal year of 49,000 acres (19,600 hectares) within current management requirements probably would cost about $100/acre ($247/hectare), still a 900 percent increase. At that rate, a normal year will cost $4,900,000 (fig. 4). Budgeting for a normal year would create a surplus of $4,369,000 compared to 1992 costs. In contrast, in 1993 the National Park Service has budgeted $1,028,000 for prescribed natural fire management, only about 24 percent of the projected normal year requirement, but twice its 1992 expenditures.

Three problems are immediately apparent:

1. Current funding is inadequate to meet projected normal prescribed natural fire needs based on pre-1988 activity levels. At this time, it is difficult to know if pre-1988 activity levels are a realistic target for post-1988 programs.

Although most parks with major PNF programs prior to 1988 had reestablished them by 1992, the normal-year level of activity may never equal pre-1988 due to more conservative prescriptions and smaller PNF zones. Nevertheless, the cost of a new hypothetical normal year of perhaps 130 fires and 20,000 acres (8,000 hectares) is likely to significantly exceed the cost of monitoring a much higher level of activity prior to 1988 because new plans require more intensive monitoring. Budgeting for a normal prescribed

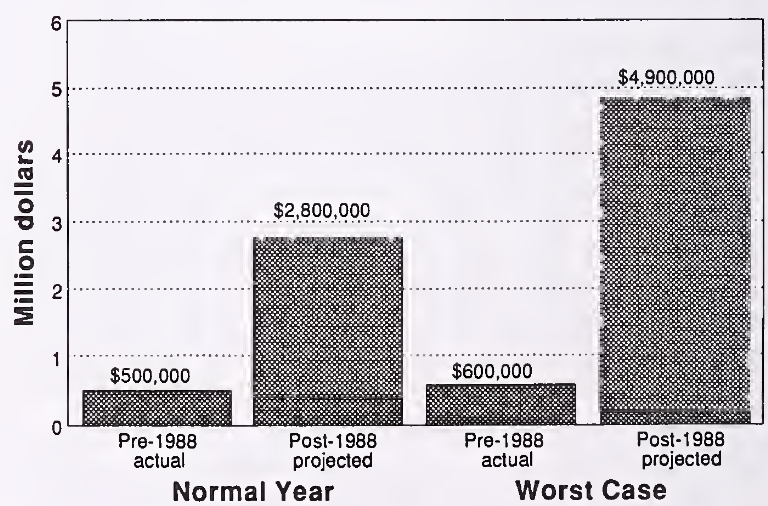


**Figure 4**—Funding requirements for prescribed natural fire management, National Park Service, in normal and "worst case" years.

natural fire year of 20,000 acres (8,000 hectares) at a hypothetical cost of $140/acre ($346/hectare) would cost $2,800,000 and consume 33 percent of the current NPS program management budget of $8,300,000. Budgeting for a pre-1988 normal year at $4,900,000 would consume 59 percent of the budget. Neither level would be sustainable within the current appropriation.

2. Banking surpluses from low PNF years in the no-year account might cover normal-year expenditure requirements, but would be disruptive to normal budget formulation and programming. Congress might interpret large surpluses in fire program management as an indication that the funds are not needed, and reduce the appropriation in response to Federal deficit reduction pressure. Also, there would be considerable pressure from within the fire organization to spend the surplus funds on other activities in order to (1) remove the implication that the fire program was overfunded, and (2) maintain target levels for other essential fire program activities during an environment of declining Federal budgets. In addition, the NPS might find it difficult to justify budget increase requests for other fire management activities while simultaneously carrying over a surplus of several million dollars for prescribed natural fire management.

3. Suppressing large prescribed natural fires because normal program funds have been exhausted is an inefficient use of government funds, because the suppression actions are likely to increase government spending rather than reduce it. Prescribed natural fires of several hundred to several thousand acres usually deplete monitoring funds rapidly, especially if they are near values at risk and require holding actions to remain within prescription. By depleting the monitoring fund, these fires hold the seeds of their own destruction, and become prime candidates for suppression. Once suppression is required, the confine strategy is usually impractical (because the fire probably grew large due to the lack of natural barriers), and the fire must be suppressed using a contain or full suppression strategy. This usually requires mobilizing many more resources and more expensive types of resources than would have been required to continue monitoring the fire.

It is ironic that in 1988 the NPS policy of using emergency presuppression funds to monitor prescribed natural fires was criticized as giving managers a "blank check" to allow PNF's to run amok, and eventually require large suppression expenditures. The program changes resulting from the Fire Policy Review Team sought to rectify this problem by imposing more strict prescriptions, increased monitoring requirements, and funding limitations. Ironically, the combination of more expensive monitoring requirements combined with limited monitoring funds ensures a recurrence of the same expenditure problem as in 1988—large prescribed natural fires will have to be suppressed at great cost to the taxpayer, only this time the fires are likely to be still within prescription and accomplishing their management goals and objectives.

Once normal program funds have been exhausted, some large PNF's that were planned to be completely free burning will be contained. For others, planned containment actions that previously had been developed as part of the individual PNF management plan will be carried out as suppression actions. In such cases, the prohibition against using emergency funds to "manage" PNF's is essentially subverted and the distinction between a wildfire suppression action and a prescribed holding action becomes meaningless.

To avoid the possibility of expensive suppression actions, some managers may decide to suppress most PNF's before they become large. Such a policy might save money in the short run, but destroy the ecological integrity of the program and create an expensive fuels management problem in the long run. The existing solution to the 1988 prescribed fire management problem may have failed to either restore ecologically viable prescribed fire programs, or to prevent the program from causing large suppression expenditures.

## POSSIBLE PROGRAM IMPROVEMENTS

To preserve ecologically significant prescribed natural fire programs in the NPS, five solutions are possible, either alone or in combination:

1. Congress can increase the base funding for PNF monitoring and management by $3,900,000. This would cover the current projected normal-year needs and dramatically reduce the chance that PNF's would have to be suppressed due to lack of management funds.

2. The rules for utilizing current appropriated funds can be changed to allow the NPS (and other Interior agencies) to utilize emergency funds for operational requirements, exclusive of base salaries and benefits. Under this solution, PNF's would be managed as unplanned, unpredictable natural events to which management must react, rather than entirely as planned, predictable resource management projects.

3. Preparedness plans, prescription constraints, and monitoring requirements can be liberalized to reduce current management costs and the probability that PNF's will have to be suppressed.

4. Management-ignited prescribed burning can be significantly expanded along PNF zone boundaries. This action would help contain PNF's within zone boundaries and reduce the frequency and cost of monitoring and holding actions.

5. Wilderness fires could be managed under a "confine" suppression strategy rather than as PNF's. A confine strategy is a legitimate, cost-effective alternative to containment or full control where wildfires can burn out to natural barriers with no threat to life or property. Current policy, however, dictates that the confinement strategy cannot be used to accomplish resource management objectives, in lieu of a PNF program.

A base funding increase of $3,900,000 would eliminate the need for other options, but is unlikely during a Federal deficit reduction program. It would allow the NPS to increase its PNF-dedicated personnel and resources, and decrease its dependence on suppression resources for preparedness planning and holding actions. Possible budget management problems associated with this solution have been discussed in problem number two.

The second alternative is probably a more feasible alternative because it would not require an increase in the current Interior fire appropriation. The base salary and support costs of personnel employed to monitor and manage prescribed natural fires could be budgeted at normal-year levels within the program management activity, as is now the case. The funding mechanism for program operations, however, would be changed. The funding requirements for monitoring and managing each fire event, which are unpredictable for any given year, would be met through the emergency operations activity.

Under this strategy, predictable staffing costs including salaries, benefits, and base support requirements such as vehicles, supplies, and equipment would be charged to a program management account. Base funds would be used to employ sufficient personnel to carry out the monitoring and holding actions necessary for line officers to certify that fires will remain within prescription. Unpredictable costs, including aerial reconnaissance flight time, travel, and premium pay would be borne by the emergency operations account.

By dividing program costs between normal programmed and emergency funds, prescribed natural fire would be managed much like search and rescue (SAR). In SAR, the basic response capability for unpredictable emergencies is funded up-front, and incidents are funded largely through an emergency fund. Most SAR could be eliminated by prohibiting rock climbing, backcountry use, and other high-risk activities, but managers have made a decision to incur a certain level of uncontrolled emergency expenditures in order to maintain certain visitor-use programs. Likewise, PNF should not be severely restricted just because it may require an unpredictable level of expenditures. To sustain the critical and pervasive influence of the natural fire process in wilderness, PNF's should be considered an unpredictable but management-sanctioned emergency just like a lost child in the wilderness.

This strategy would reduce the probability of suppressing a prescribed natural fire that is within prescription and meeting all program goals and objectives just because insufficient funds exist within a particular part of the fire appropriation.

Modifying preparedness planning, prescription, and monitoring requirements would free contingency resources and reduce monitoring costs, but a full discussion of possible alternatives is beyond the scope of this paper. Probably the most productive changes could be made by a more reasonable assessment of how to define PNF's of no significance or risk. The NPS fire situation analysis process provides a good framework for this assessment. Through that process, augmented by improved fire weather and fire growth modeling, managers should be able to predict which new starts are likely to require suppression resources in the future. This would improve the current system of taking suppression action against potential PNF's based on current preparedness levels alone.

Increasing the use of management-ignited prescribed fire as a tool to secure PNF zone boundaries should be part of the preferred alternative, in compliance with recommendation number seven from the Fire Management Policy Review Team (USDI, USDA 1989). A significant increase in project funding and project accomplishment would be required to accomplish this goal. This program also operates under significant political and prescriptive constraints, however, and only about 50 percent of the projects funded between 1989 and 1992 have been carried out. A full discussion of these problems is also beyond the scope of this paper.

Managing wilderness fires under a "confine" suppression strategy would eliminate funding constraints, but would require a major change in Departmental fire management policy, allowing resource management objectives to be accomplished through a suppression strategy. The definition of "confinement" would have to be expanded to clearly permit it to be used for nonsuppression purposes. Otherwise, it might be difficult to defend the cost effectiveness of allowing fires to burn for several months when they could have been controlled more cheaply at inception or during dormant periods.

Under the current system, managers have the option of utilizing a confinement strategy for PNF's that have to be suppressed because program funding has been exhausted. If PNF's are confined and allowed to run their natural course, there is little real distinction between the effect of managing the fire as a PNF or a wildfire. Since managers have this de facto ability to access emergency funds to accomplish resource management objectives, overall program credibility would be enhanced by either adopting option number two or five to make this a de jure ability.

## CONCLUSIONS

The fundamental purpose of prescribed natural fire management is to maintain the ecological integrity of existing ecosystems by sustaining the pervasive influence of a powerful natural process. A prescribed natural fire program that permits only a few, generally small, fires to burn under highly restricted conditions, because of prescription, preparedness planning, or funding constraints, cannot accomplish any significant resource management objectives in most parks and cannot be justified on that basis.

Five years after the 1988 Yellowstone fires, NPS prescribed natural fire programs are operating at greatly reduced levels compared to number of fires and acres burned pre-1988. It is likely that continued disruption of natural fire regimes will produce a negative feedback loop similar to what has occurred in vegetative communities outside PNF zones. Constraints on the size, number, and intensity of PNF's will produce unnatural fuel and vegetative structure, which will increase the likelihood that future fires will exceed prescription, resulting in even more suppression actions and new constraints, such as reductions in the size of PNF zones and an increase in contingency reserve forces required to certify that the program can continue. A possible outcome of this downward spiral could be that programs eventually will be restricted to vegetative communities in which PNF risks are negligible, primarily subalpine and alpine zones.

This situation requires a reassessment of whether PNF programs can accomplish stated goals and objectives. The recommendations of the Fire Management Policy Review Team and the General Accounting Office have been adopted in a somewhat uneven manner, with emphasis on greatly reducing program risk at the expense of maintaining the

influence of natural fire in wilderness areas. Current policies on the availability of funding and resources have mirrored this conservative approach. To reestablish ecologically significant programs in parks, several alternative strategies for funding and resource availability need to be considered. A combination of new policies allowing limited access to emergency funds, redefining the conditions under which PNF's can continue to burn under preparedness plans, and increasing management-ignited prescribed fire to secure PNF zone boundaries probably offers the best alternative.

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# Programs and Future Opportunities

## Panels



# Alternatives for Implementing Fire Policy

James K. Agee

**Abstract**—We know that the natural fire regimes of park and wilderness ecosystems are extremely variable. Past management practices (primarily fire exclusion), other resource constraints (endangered species, air quality), location and shape of preserves, and new natural fire policy guidelines suggest that natural fire may be either inappropriate because of ecological changes, or impossible because of the plethora of overlying layers of management constraints. The goals of fire plans in natural areas need to be well-defined, and if they cannot be met by natural fire alone, a variety of alternatives are available (prescribed fire, fuel modification) to achieve park and wilderness management objectives.

When parks and primitive areas (which were later called wilderness) were first established, many of them were already experiencing a wide variety of impacts from modern culture: elimination of Native American burning, killing of predators, introduction of alien plants, and eventually, significant recreational impacts. As we know, a blanket policy of fire exclusion emerged early in the 20th century and was applied to preserve these lands as well as all other wildlands in America.

Parks and wilderness areas are managed for their natural values, and natural disturbance is a part of these ecosystems. Some of the natural processes in these preserves have continued unabated over time: the "let-it-blow" policy for hurricanes, the "let-it-glow" policy for volcanoes, and the "let-it-grind" policy for glaciers. But the long human interaction with fire placed it in another category. It was one of the few large-scale disturbance processes we could control, at least most of the time. And so we did. There was to be no "let-it-burn" policy...at least for a while.

The Leopold Report in the early 1960's, with its recommendations to allow or mimic natural disturbances and restore a "vignette of primitive America" at least on local scale, was instrumental in changing the fire exclusion policy. For the last 25 years we have experimented with fire as an ecosystem restoration and management technique in park and wilderness ecosystems.

## ELEMENTS IN FIRE PLANNING

Successful management of fire in these areas requires integrating all the important variables: the historic role of fire in the ecosystem, the unnatural changes caused by fire exclusion policies, and management constraints such as endangered species that rely on a particular ecological stage, or air quality constraints. The challenge is to restore and maintain fire as a natural process in the face of these many constraints (Agee 1974).

## The Natural Role of Fire

The natural role of fire can be understood through a concept known as the fire regime. One way to define fire regimes is by effects on dominant plants. The three categories here—low, moderate, and high—can be applied to the common forest types of the Pacific Northwest (fig. 1), and are related to the fire environments of temperature and moisture just as the forest types are. In the low-severity fire regime (fig. 2), most of the fires are of low severity, while in the high-severity fire regime, most of the fires are high severity. The moderate-severity fire regime has a complex mix of low-, moderate-, and high-intensity fire (Agee 1993).

The forests of any region can be placed into one of these three broad categories. In the Pacific Northwest, for example, the moist western hemlock (*Tsuga heterophylla*)/ Douglas-fir (*Pseudotsuga menziesii*) type has a high-severity fire regime. Fires are very infrequent but usually

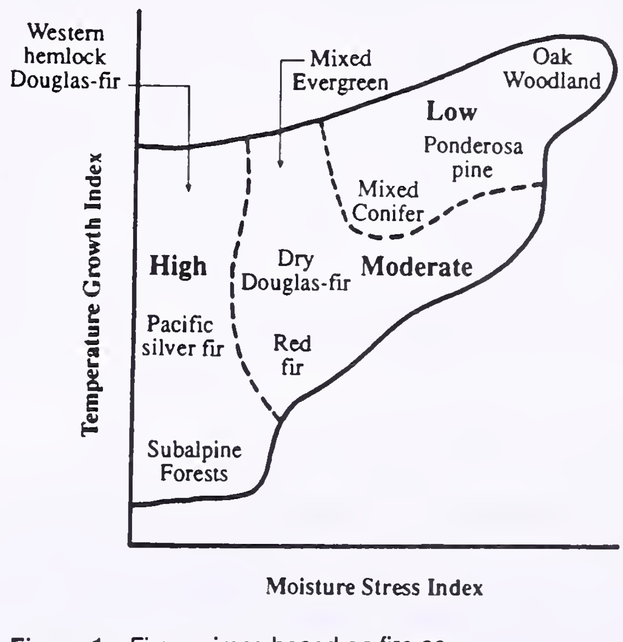


**Figure 1**—Fire regimes based on fire severity. Stands in low-severity fire regimes have 20 percent or less of the basal area removed by fire, while stands in high-severity fire regimes have 70 percent or more of their basal area removed (Agee 1993).

In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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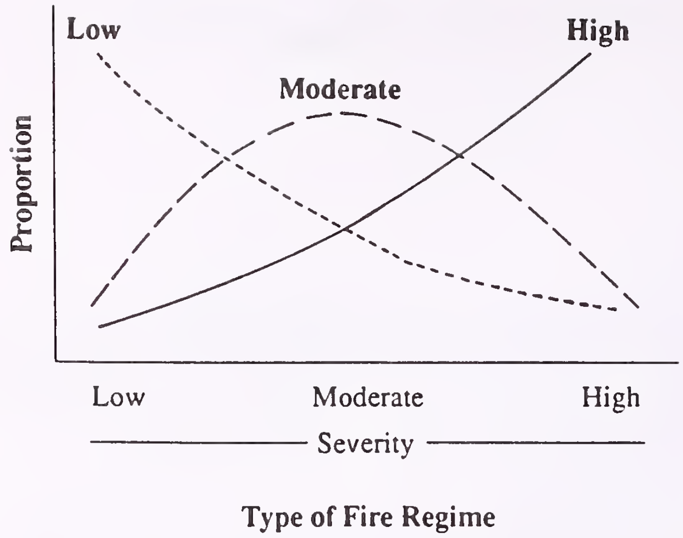


**Figure 2**—Variation in fire severity within a general fire severity type. The general fire severity types differ in the proportion of each fire severity level present, with the moderate-fire severity regime having the most complex mix of low-, moderate-, and high-severity fire (Agee 1993).

result in high tree mortality, beginning a new even-aged stand on its way to old growth (Munger 1940). Subalpine forests also burn infrequently and fires are stand-replacement events. Because of their marginality for tree establishment, these areas are often still open landscapes after a century (Kuramoto and Bliss 1970).

The moderate-severity fire regime is exemplified by red fir (*Abies magnifica*) forests. Patches of varying fire severity occur over the landscape, ranging from underburns, to significantly thinned stands, to stand-replacement patches (Pitcher 1987). Older stands have less probability of stand replacement because of increased fire resistance of the dominant firs. Drier Douglas-fir forests, many grand fir (*Abies grandis*) types, and climax lodgepole pine (*Pinus contorta*) forests also have moderate-severity fire regimes (Agee 1993). The classic low-severity fire regime is ponderosa pine (*Pinus ponderosa*) forest (Biswell 1973; Weaver 1943). The patch structure and regeneration of these forests was intricately linked to fire disturbance. So a critical initial point is to recognize that fire management alternatives must be tailored to the variability in fire regimes: solutions cannot be the same for every ecosystem.

## Changes Due to Fire Exclusion

The second important element in planning is that significant ecological changes—species composition, structural, functional—have occurred in many fire regimes due to fire exclusion policies. Because of this, the process of fire cannot always be reintroduced with the same effects it once had under more natural conditions. Species composition changes have favored shade-tolerant species—true fir and Douglas-fir—particularly in mixed conifer forests once dominated by ponderosa pine (Gruell and others 1982). The slow decline of whitebark pine (*Pinus albicaulis*) forests, as they are slowly replaced by subalpine fir (*Abies lasiocarpa*), is a natural process, but it is occurring at a scale likely unprecedented in recent centuries (Morgan and Bunting 1990).

Structural changes in stand architecture have linked ground fuels to crown fuels at the level of the stand, and many forests have experienced many changes in landscape pattern. This may have consequences on future fire behavior, which will be discussed later. Patch size in ponderosa pine or mixed-conifer forest already is seldom discernible. In moderate-severity fire regimes such as red fir, control of all but high-severity fires has encouraged lodgepole pine over red fir regeneration. In chaparral landscapes of California, small, complex mosaics of various-aged chaparral have been replaced by larger patches burning in more uniform fuels (Minnich 1983). Functional changes due to fire exclusion include the increasing importance of insects and disease as disturbance agents in the absence of fire, loss of habitat for some wildlife species and possible gains for others, and changes in nutrient cycling. Yet not in all ecosystems can significant ecological changes due to fire exclusion be documented. In the Olympic Mountains, for example, fire exclusion had a very small impact because the natural fire return intervals are centuries long (Agee 1985).

So a second major point is that fire management solutions must incorporate the degree of human-caused ecological change, and this will also vary by ecosystem: insignificant in some, past the point of no return in others. Few parks and wildernesses are in totally "natural" states. While this does not give us license to ignore our goal of getting as close as we can, it does justify intervention (such as the use of prescribed fire) to restore a desired set of ecosystem states or mimic natural fires.

## Ecosystem Management Concerns

The simple—or perhaps more accurately, simplistic—solution is to let fire again roam free in the forest. But that is not ecologically or politically desirable in most situations. Parks and wildernesses are not ecological islands; they are almost always tied closely to neighboring landscapes in a biological or political context, and that tie goes both ways.

In the Olympic Mountains of Washington, most of the old growth forest on which the northern spotted owl (*Strix occidentalis* var. *caurina*) depends is in either park or wilderness, having been logged elsewhere. This logging has resulted in the owl being a threatened species. Large-scale intense natural fires in park and wilderness—typical of this ecosystem—could result in local extinction of the spotted owl. So land management practices outside parks and wilderness have affected potential future management of natural fires inside these preserves, irrespective of safety, smoke, or fire control issues.

On the other hand, smoke or escaped fires from inside parks and wilderness can threaten values outside these areas. This is the crux of the new "ecosystem management" paradigm: natural areas are inevitably going to be tied to outside lands, and vice-versa, more than ever before.

## GOALS FOR FIRE MANAGEMENT

Appropriate goals for park and wilderness fire management have been debated over the years (Bonnicksen and Stone 1982; Parsons and others 1986). Should we strive for a **structural** solution—the vegetation that a natural fire regime would have created, difficult as that might be to define—or should we try to reintroduce the natural **process** and take whatever outcome results (Van Wagner 1985)? Which is closest to meeting park and wilderness objectives?

An example of how a structural approach might be interpreted, on a landscape level, is shown in figure 3. The stand age structure is assumed to follow a negative exponential distribution (A) common to some boreal forests. Fire has an equal probability of burning any age class, so fire exclusion results in an "excess" of stands of all ages beyond the date fire exclusion began, and a dearth of new stands. If fire were reintroduced in a **process**-related approach, the hole in age classes would age over time and slowly "slide" off the right side of the graph, eventually recreating a negative exponential distribution. A **structural** solution to the same problem is shown by figure 3, B-C. To make up for the gap in (A), prescribed stand-replacement fires are added to the natural fires to create extra young stands, shown as an "excess" in (B). The excess is thinned or fertilized to increase its apparent age and recreate the landscape mosaic expressed by the negative exponential distribution (C).

This is a pretty radical approach, and depends on a host of assumptions about natural forest age-class structure, many of which are violated in forests of the Western United States. But it contrasts two very different ways to think about fire reintroduction. Many reintroductions of prescribed fire include less severe structural objectives than those described earlier, but defined at a stand level rather than a landscape level. For example, in many national park mixed-conifer forests, "natural" flame lengths (process oriented) are prescribed at the same time as structural parameters such as species and size classes (for example, to save older cohorts of ponderosa pine). Both structure and process approaches may be useful to consider in park and wilderness management, depending on the situation, and they are not mutually exclusive options. The focus of this paper is more on alternatives for implementing policy rather than debating what the policy should be. Nevertheless, there is a lot of room for local interpretation of legislation and policy, and no one predetermined landscape configuration for any park or wilderness (Christensen and others 1989). This is brought home by the potential magnitude of effect of global warming on park and wilderness vegetation. For example, while we may argue about appropriateness of structural or process goals for ponderosa pine forests, the environments that nurture those spectacular forests may be several thousand feet higher in elevation over the next 50-100 years. Arguments about fine-tuning fire policy may be moot.

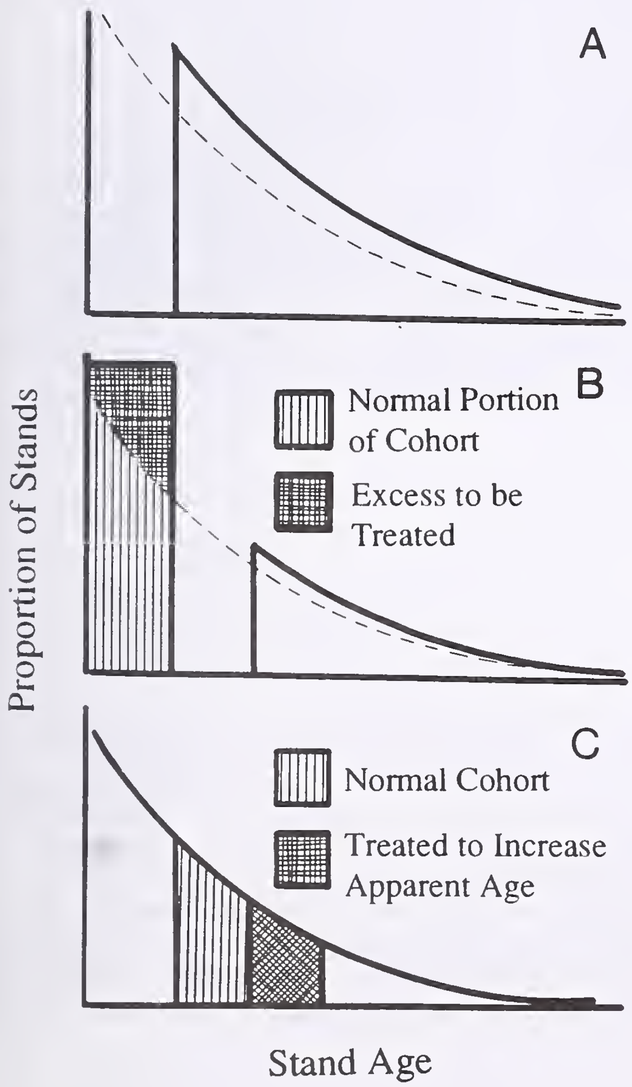


**Figure 3**—A radical structural approach to restoring landscape structure: A, a forest that has equal probability of any stand age burning (usually high severity) in a given year, in a forest where many small stands exist compared to the total forest area, often has a negative exponential age distribution (see Van Wagner 1978), shown as the dashed line. Fire exclusion results in no recruitment of young stands, shown by the solid line; B, a structural landscape option might be to allow natural fires to burn and create additional young stands by prescribed burns of high intensity, as the age class gap moves to the right; C, treatments such as thinning can increase the size of stems in some of the younger stands, increasing apparent stand age and structure, and more quickly restore a natural landscape pattern.

## ALTERNATIVES FOR RESTORING THE NATURAL ROLE OF FIRE

What are the alternative solutions? Others at this conference have described the plethora of management constraints facing park and wilderness fire managers. It's clear that few parks or wildernesses can truly recreate the role of natural fire by a prescribed natural fire policy alone. Too many natural fires are going to have to be suppressed, because of management concerns: too early in the season, too near the boundary, possible air quality issues, and other constraints (Daniels, these proceedings; Brown, these proceedings). Therefore, it is not enough to consider approval of a fire management plan as successfully meeting objectives. How completely the natural role of fire is being restored and maintained is the more appropriate criterion.

The alternatives fit into five separate categories, each of which will be briefly described: no action; liberal use of confine and contain strategies under a fire suppression plan; application of a prescribed natural fire plan; use of prescribed fire in addition to a conservative prescribed natural fire plan; and use of fuelbreaks in addition to prescribed natural fire or prescribed fire.

The "no action" alternative is where many of our parks and wildernesses are now, either because plans were suspended after the 1988 fires or no plans have ever been approved. This alternative cannot meet management objectives unless fire was not a part of the natural environment, a rare situation. The second alternative, that of having a total fire suppression plan but using "confine" and "contain," rather than "control," as primary suppression strategies, is a poor substitute for a proactive plan, and invites legal and administrative problems. "Confine" and "contain" strategies are important fire suppression options, but they are not appropriate as primary strategies to achieve natural fire management objectives.

A conservative prescribed natural fire plan will work best in those ecosystems where fire is not going to spread over wide areas, is predicted to be of low intensity and easily controllable, or where significant natural barriers to spread are found. It may be the only politically acceptable option in many other areas. The result of this alternative will generally be less fire than might be appropriate from a purely ecological view. It may also result in a shift of fire severities, particularly in the low- and moderate-severity fire regimes, to higher severity fires. It will continue to exacerbate the loss of landscape pattern if applied very conservatively, which itself may reduce natural stand pattern barriers to fire spread (van Wagtendonk, these proceedings).

Prescribed fires can be used to reduce fuel loads and restore a more natural forest structure before prescribed natural fires are allowed to burn (fig. 4). Prescribed natural fires in the forest shown in figure 4B would now burn not only within the range of historic intensity but would also be in the range of historic severity, restoring more fully the effects of the historic fire regime. It is important to look at all aspects of the fire regime (frequency, magnitude, intensity, duration, extent, seasonality, synergism with other disturbances) when applying prescribed fire.

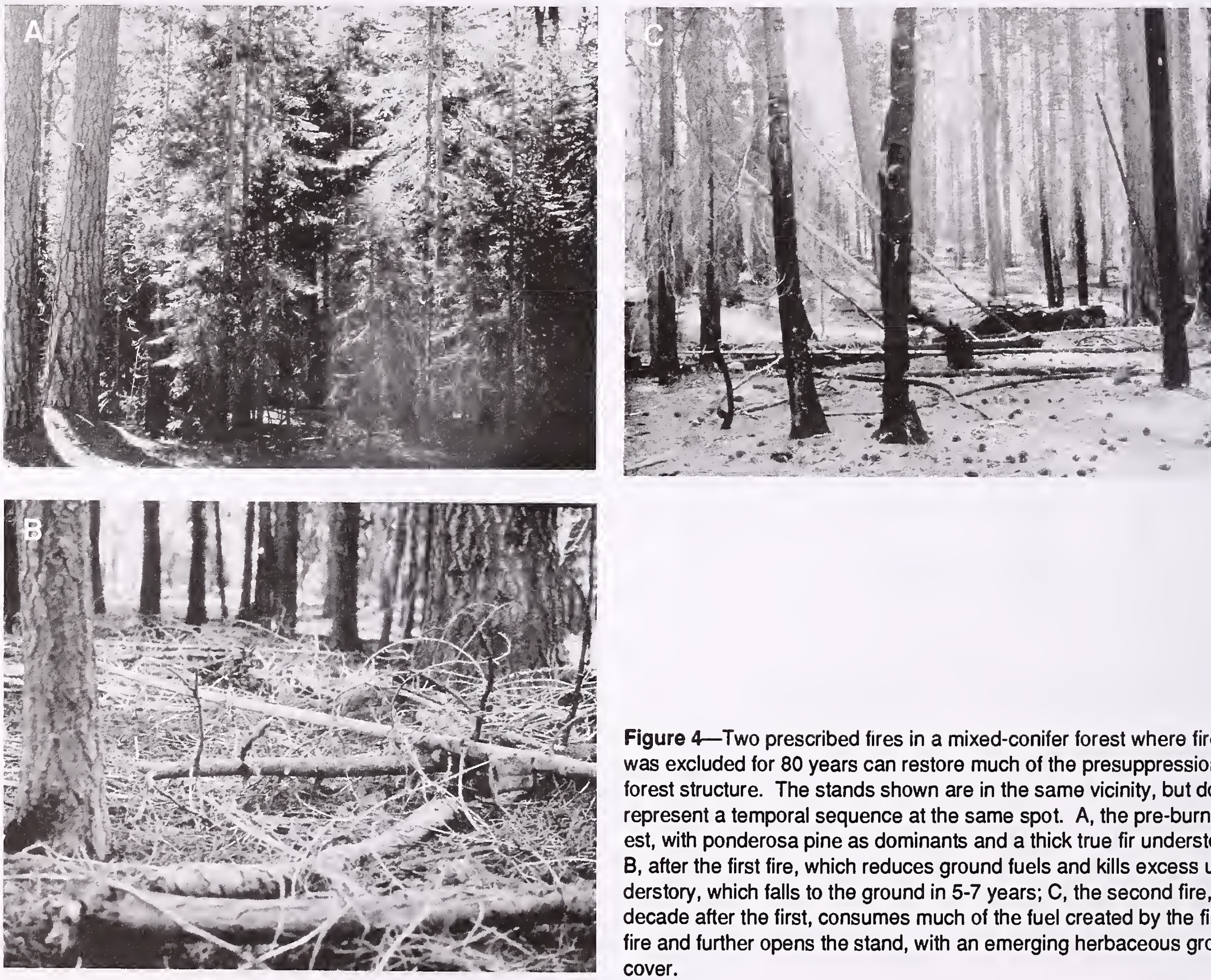


**Figure 4**—Two prescribed fires in a mixed-conifer forest where fire was excluded for 80 years can restore much of the presuppression forest structure. The stands shown are in the same vicinity, but do not represent a temporal sequence at the same spot. A, the pre-burn forest, with ponderosa pine as dominants and a thick true fir understory; B, after the first fire, which reduces ground fuels and kills excess understory, which falls to the ground in 5-7 years; C, the second fire, a decade after the first, consumes much of the fuel created by the first fire and further opens the stand, with an emerging herbaceous ground cover.

Fires prescribed only for flame length, for example, ignoring seasonality and duration, may not have desired effects. Excessive duff reduction during spring fires can subject mature pines in mixed-conifer forests to significant fine-root mortality as they enter the dry season (a seasonality effect), and set up later bark beetle attacks (a synergism effect) (Swezy and Agee 1991).

The nature of fires in chaparral makes a prescribed natural fire policy difficult to manage. Prescribed fires may be a more appropriate way to reintroduce and maintain fire as an ecological process in these ecosystems. Blacklining by burning ridgelines in late spring may help create defensible fuelbreaks for autumn prescribed fires.

Human-created fuelbreaks may be the most controversial alternative, as they are by far the most subjective and obvious human-influenced treatment discussed here. We have relied on natural fuelbreaks (oceans, lakes, riparian corridors, rocky bluffs or ridges) extensively in prescribed natural fire programs, but have little experience with networking natural and human-created fuelbreaks together. Fuelbreaks, linear areas in which fuels are reduced by thinning or pruning, may be helpful in securing boundaries of prescribed natural fire zones and therefore allowing a broadening of prescribed natural fire prescription criteria.

There may be few natural fuelbreaks between a prescribed natural fire zone and adjacent lands. Many parks and wildernesses have transparent boundaries with adjacent wildlands. Prescription criteria for prescribed natural fires within the zone are likely to be less restrictive—indeed, there might even be a chance of allowing a natural fire to burn—if some fuel modification exists between the zone and adjacent lands. Fuelbreaks need not be totally cleared areas, or manually created, or straight lines, or crisscrossed grids across preserve landscapes. Some could be created and maintained with prescribed fire. Traditional fuelbreaks are very open and obviously manipulated (fig. 5A), but a more "light on the land" approach is possible to link preserve boundaries or internal natural fuelbreaks together (fig. 5B). Both reduce surface fire potential; the denser residual canopy in figure 5B could carry independent crown fire better, but shades the understory fuels more and restricts understory regrowth.

Fuelbreaks should be applied more than they historically have been at the margin of park and wilderness areas. Within such areas, there will remain controversy over both the appropriateness of such corridors and their effectiveness either in serving to slow prescribed natural fires that need confinement, or to allow managers to sleep more soundly during a prescribed natural fire event. We need to consider the creative use of fuelbreaks as an additional tool in our fire management bag.


**Figure 5**—A, fuelbreaks can be very obvious and inconsistent with the expectation of little human influence in parks and wilderness; B, a more "light on the land" approach can achieve many of the same objectives while the appearance of manipulation is less obvious.

## CONCLUSIONS

The alternatives in implementing fire policy are limited. We must recognize the human impact in and around each park or wilderness, and the human intervention and manipulation necessary to preserve natural ecosystem states and processes. We should not rely on chance alone to make an unnatural world natural. Innovative operational strategies, such as large-scale aerial ignition of prescribed fire, are available to us now, subject to social and political constraints. Fuelbreaks in wilderness may be appropriate in selected situations, but will more likely find better constituent acceptance along boundaries of parks and wilderness. We will only overcome those sociopolitical constraints by having a well-designed landscape plan with the outcomes of action, and no action, clearly articulated.

The first 25 years of park and wilderness fire show a rapid expansion of fire use, although nowhere to historic fire frequencies. The recent trend to more conservative application of prescribed natural fire means we will either continue to unnaturally reconfigure our preserve landscapes, or develop innovative strategies in addition to prescribed natural fire to restore the natural role of fire to these landscapes.

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# Large Fires in Wilderness Areas


## Jan W. van Wagtendonk



**Abstract**—To truly allow fires to play their natural role in wilderness ecosystems, it is sometimes necessary to have large fires of long duration. Large fires are ecologically significant events that drive many other ecosystem processes. However, these fires pose significant management concerns. As a result, managers may limit the opportunity for fires to play their natural role. Risk of escape out of prescribed natural fire zones, endangerment of human life and structures, and smoke are all concerns that must be addressed before fires are allowed to grow large. Experience in California has shown that smoke is the most frequent limiting factor, while fire escape and public safety have been important issues in Wyoming and Montana. A decision to limit the size or duration of natural fires is a decision to alter natural ecosystem function. Such a decision must be made with the best information available about possible ramifications.


One of the most complex problems facing managers of wilderness and parks is dealing with large prescribed natural fires. Largeness itself is not as important as the size of the fire in relationship to the size of the area. A small fire in a small area poses problems similar to a large fire in a large area.

If the fire is predicted to burn a significant portion of a wilderness or park, several questions must be considered. First, large fires must have played an ecological role in the area historically. In addition, the fuels and predicted behavior of the fire must be within their natural ranges. Concerns such as the risk of escape, smoke, safety, and availability of fire-fighting resources also need to be addressed.

## ECOLOGICAL ROLE OF FIRE

Before any naturally caused fire is allowed to burn in a park or wilderness, the ecological role of fire in that area must be determined. This can be accomplished through an analysis of historic fire records, vegetation patterns, fire scars, and charcoal deposits.

In Yosemite National Park, van Wagtendonk (1986) found that over 2,000 lightning fires had burned in the park since 1930. Between 1930 and 1972 when the prescribed natural fire program was initiated, only three of those fires were greater than 400 hectares (1,000 acres) in size. During the past 22 years (1972-93) 23 lightning-caused fires have grown larger than 400 hectares (1,000 acres). Five of the 23 were wildfires starting outside of the prescribed natural fire zone, and one of those was over 7,000 hectares (17,300) acres.


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Obviously, large fires are ecologically significant events in Sierra Nevada ecosystems. This has been underscored by analyses of fire scars. Swetnam and others (1992) discovered an unusual fire event in the year 1297 as recorded in giant sequoia (*Sequoiadendron giganteum*) growth rings. Evidence of growth release and postfire establishment extends from the southern to the central Sierra Nevada. Such evidence is corroborated by charcoal deposits found in meadow and lake sediments (Anderson and Carpenter 1991).

In Yellowstone National Park, Romme and Despain (1989) investigated historic fire size using vegetation patterns and fire scars. They found evidence of very large fires at intervals of 300 years or more, with intervening periods of no fires or very small fires. Whitlock and Bartlein (1993) found layers of charcoal in sediments dating back to the early Holocene. The recent fires in Yellowstone indicate that large fires still play an important ecological role.

If natural processes are to be replicated in wilderness and parks, large fires will have to be allowed to burn. If this is not possible because the area is too small or other values preclude the implementation of a prescribed natural fire program, surrogates for fire must be found (Christensen 1991). Prescribed burns, mechanical manipulation, and artificial cutting are possible options. In any case, it is important that naturally managed ecosystems not be denied ecologically significant events.

## MANAGEMENT CONCERNS

Managers are most often concerned about the risk of a fire escape and the safety of their crews and the public. Secondary concerns include the impact of a large fire on fire-fighting resource availability and the impact of smoke generated by the fire.

The fear that a prescribed natural fire will leave the boundary of one area and enter an adjacent ownership is only exceeded by the fear that one's career might be at risk by deciding to allow it to burn. Many times the decision to extinguish a fire is based on that latter fear. Steps have been taken to remove as much of the uncertainty as possible from those decisions.

Much of the risk has been lessened by new procedures established after the 1988 Yellowstone fires. For instance, in the National Park Service a two-step process was implemented for determining if a natural ignition should be allowed to burn, and then, once started, whether or not it should be allowed to continue burning (Norum 1993). The first step involves an evaluation of: ignition source and its location in the park, existing and predicted Burning Index values, predicted fire growth, potential smoke impacts, environmental impacts, threats to humans and other values at risk, and preparedness requirements. A Fire Situation Analysis is used to document this evaluation.

Daily certification by the park superintendent is required to allow a prescribed natural fire to continue burning. This certification includes a statement that all fires are anticipated to stay in prescription and that personnel and resources are available to monitor fires and suppress fires that may exceed the prescription.

Similar procedures are in place in the Northern Region of the Forest Service (Tomascak 1993). New starts are evaluated with a checklist that covers the same points as the Park Service's process. Continuing fires are covered by burn plans, which include maximum allowable perimeters, fire growth projections under normal and severe weather conditions, holding actions, fire effects analyses, and daily revalidations by a line officer.

Recent advances in fire behavior prediction capabilities give hope that reasonably accurate estimates of fire growth and intensity can be made (Andrews 1986; Andrews and Chase 1989; Burgan and Rothermel 1984; Rothermel 1983). The Yellowstone fires added to these advances by providing the opportunity to test new technologies under extreme conditions (Hartford and Chase 1991; Rothermel 1991). Computer modeling will increase the ability to predict large-fire behavior and growth over complex terrain with varying weather conditions (Finney, these proceedings). All of these tools will help a manager to delineate a maximum allowable perimeter that is ecologically sound and defensible, thereby reducing the risk of escape.

Managers of areas that are prone to large fires may have to consider having extra crews on hand to deal primarily with prescribed natural fires. These crews could be shared between neighboring parks and forests that have active programs, with the understanding that their first priority was the monitoring, holding, and suppressing of prescribed natural fires. Contingency plans for wildfires would only include the crews after all other resources had been depleted.

Smoke from large fires in wilderness must be dealt with before a fire even ignites. Coordination between personnel from resource agencies and local pollution control districts is essential to develop mutually agreeable procedures. For example, two large fires in Yosemite National Park in 1991 produced smoke problems in adjacent communities resulting in several nuisance complaints. Meetings the next winter resulted in agreements to share the cost of monitoring equipment and to set quantitative limits for initiating holding actions. These meetings have resulted in increased understanding and awareness of each agency's regulations and legal mandates (Chambers and Duncan, these proceedings).

## A CASE HISTORY

Prescribed natural fire management began in Yosemite National Park in 1972 with the establishment of prescribed natural fire (PNF) zones including 25 percent of the park (Botti 1986). Initially these zones were confined to alpine, subalpine, and limited lodgepole pine (*Pinus contorta*) areas where few fires had occurred in the past. Numerous barren areas prevented fires from becoming large. A key to the early success of the program was the conservative approach taken in the beginning. The zones were expanded gradually as experience was gained. Today they cover 263,556 hectares (651,247 acres) or 87 percent of the park.

A total of 462 fires have been allowed to burn over 20,000 hectares (50,000 acres) in the PNF zones during the 23 years of the program (table 1). The number of fires has varied from a high of 43 in 1988 to a low of four in 1993. No fires were allowed to burn in the zones in 1989 because the recommendations of the National Fire Management Policy Review Team had not been submitted (Norum 1993). Yosemite was one of the first parks to get back on line with a prescribed fire management program in 1990.

Over 60 percent of the prescribed natural fires were less than 0.1 hectares (0.25 acres) in size, usually only a single tree and a small area at its base (table 2). Most of these small fires occurred in the red fir (*Abies magnifica*) and lodgepole pine types where weather and fuel conditions are usually not adequate for burning. Only 18 fires were larger than 400 hectares (1,000 acres), and these were primarily in the white fir (*Abies concolor*) mixed conifer type. Moderate-sized fires between 4 and 400 hectares (10 and 1,000 acres) were most prevalent in the Jeffrey pine (*Pinus jeffreyi*) and red fir types.

Other than in 1989, only 25 fires in the prescribed natural fire zone have had appropriate suppression action taken on them. Violation of the ambient particulate standard in the park and excessive smoke in nearby communities resulted in the partial containment of 11 fires. Containment action was also taken on 13 fires that were predicted to cross the zone boundary and one fire when fire-fighting resources were low. Only one fire, the 1991 Ill Fire, exceeded its maximum allowable perimeter and had to be declared a wildfire.

The Ill Fire was burning in the Illilouette Creek drainage where the Starr King Fire had burned 1,600 hectares (4,000 acres) in 1974 (van Wagtendonk 1978). The 1974

**Table 1**—Number of prescribed natural fires and area burned in Yosemite National Park, 1972-1993

| Year | Number | Hectares | Acres |
|---|---|---|---|
| 1972 | 8 | 0.13 | 0.31 |
| 1973 | 27 | 22.70 | 56.09 |
| 1974 | 22 | 1,672.08 | 4,131.71 |
| 1975 | 20 | 313.18 | 773.87 |
| 1976 | 35 | 325.31 | 803.83 |
| 1977 | 24 | 60.61 | 149.76 |
| 1978 | 33 | 1,005.93 | 2,485.65 |
| 1979 | 6 | 31.66 | 78.24 |
| 1980 | 25 | 2,510.48 | 6,203.39 |
| 1981 | 39 | 1,320.27 | 3,262.39 |
| 1982 | 5 | 0.47 | 1.17 |
| 1983 | 6 | 671.86 | 1,660.16 |
| 1984 | 20 | 431.91 | 1,067.25 |
| 1985 | 22 | 1,523.94 | 3,765.65 |
| 1986 | 8 | 1,541.12 | 3,808.11 |
| 1987 | 40 | 2,862.40 | 7,072.98 |
| 1988 | 43 | 5,109.27 | 12,265.00 |
| 1989 | 0 | 0.00 | 0.00 |
| 1990 | 21 | 81.26 | 200.80 |
| 1991 | 20 | 527.72 | 1,304.00 |
| 1992 | 34 | 233.43 | 576.80 |
| 1993 | 4 | 0.16 | 0.40 |
| Total | 462 | 20,100.19 | 49,667.56 |

Table 2—Size classes of prescribed natural fires, Yosemite National Park, 1972-1993

| Size class | | Number of fires | Percent in size class | Percent of area burned |
|---|---|---|---|---|
| *Hectares* | *Acres* | | | |
| 0 - 0.09 | 0 - 0.25 | 289 | 62.55 | 0.04 |
| 0.1 - 3.9 | 0.26 - 9 | 79 | 17.10 | 0.43 |
| 4 - 39 | 10 - 99 | 31 | 6.71 | 2.50 |
| 40 - 119 | 100 - 299 | 23 | 4.98 | 7.24 |
| 120 - 399 | 300 - 999 | 22 | 4.76 | 18.52 |
| 400 - 1,999 | 1,000 - 4,999 | 18 | 3.91 | 71.27 |

fire filled Yosemite Valley with smoke at night, so it was controlled before it had a chance to burn fuels that were subsequently burned by the Ill Fire 17 years later. Had the Starr King Fire not been suppressed, the Ill Fire would not have been as intense and probably would not have exceeded its perimeter.

The Illilouette Creek basin is an excellent example of the effects a long-term program has on large fires (van Wagtendonk 1993). In 1981 another fire burned to the edge of the Starr King and went out. Reburns into the 1974 burn occurred in 1980 and in 1988, but these were greatly reduced in intensity and soon went out. Other fires in intervening years are filling in the jigsaw puzzle of burned areas (fig. 1). No single fire has been greater than 1,600 hectares (4,000 acres); the pattern is self limiting.

No prescribed natural fire has resulted in a fatality or serious injury to fire crews or the public since the program began. Indirect containment actions can be, with proper precautions, less dangerous than direct attack. Public awareness of the program is high, and visitors are

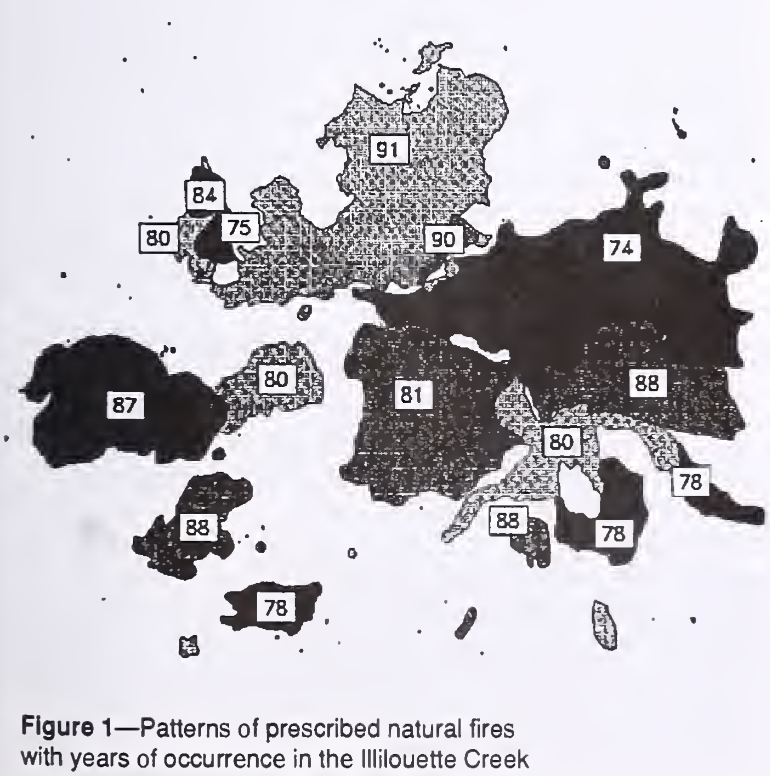


**Figure 1**—Patterns of prescribed natural fires with years of occurrence in the Illilouette Creek basin, Yosemite National Park, 1974-91.

made aware of areas of the park that are burning through radio announcements, newspapers handed out at the entrances, and signs posted at appropriate trailheads. Areas are closed to public entry when necessary.

The success of the program can be measured by the closeness of the calculated fire return interval to the hypothesized interval for each vegetation type. Table 3 shows the total area burned in the major types, the percent of that type that has been burned, and the return interval. In ponderosa pine (*Pinus ponderosa*) mixed conifer, only 503 hectares (203 acres) out of 2,545 hectares (1,030 acres) have burned with prescribed natural fires for a return interval of 106 years. This is much longer than the 10 to 12 years for that type reported by Kilgore and Taylor (1979) and van Wagtendonk (1985). This is also the area where the park has done the most prescribed burning to offset the years of fire suppression and subsequent buildup of fuels. With those acres included, the return interval is closer to 20 years. Additional work needs to occur in this type.

The white fir mixed conifer type has been most extensively burned, with a calculated return interval of 49 years. This is too high, because few data exist to estimate the real value. The largest fires have occurred in this type, since weather and fuel conditions are conducive to burning and lightning ignition sources are prevalent (van Wagtendonk 1991).

The red fir, Jeffrey pine, and lodgepole pine types all have return intervals within the estimated ranges for those types. Although there are plentiful lightning strikes in these types, sparse fuels and moist weather conditions make large fires unlikely. Lodgepole pine in the Sierra Nevada seldom exhibits the stand-replacing fire regime so common in the Rocky Mountains, and the intervals appear to be longer than those hypothesized for Yellowstone (Romme 1993).

Only 26 hectares (64 acres) of the whitebark pine (*Pinus albicaulis*) type have burned during the past 22 years. With a calculated return interval of over 21,000 years, whitebark pine cannot be considered a fire type. Lightning strikes at the high elevations where this pine occurs are usually accompanied by precipitation.

## FUTURE OPPORTUNITIES

Large wilderness and park areas give us the opportunity to see how fire influences natural ecosystems. We need to look very carefully at our prescriptions to check that we are not precluding ecologically significant events from playing their natural role. In particular, we need to look at restrictions on the number and size of ongoing fires as prescription parameters. These are often implemented to preclude depleting fire-fighting resources. Perhaps it would be better to anticipate those needs and have resources available specifically for prescribed natural fires. Intensity prescriptions also limit effective fires and might not be necessary when considered on a case-by-case basis.

Cooperative efforts with other agencies and the private sector can also open opportunities. Sharing resources is critical in this time of shrinking budgets. Public information efforts are essential to gain understanding and support for the prescribed natural program. Consultations

**Table 3**—Area burned by prescribed natural fires in conifer vegetation types and calculated return intervals, Yosemite National Park, 1972-1993

| Vegetation type | Area in type | Area burned | Percent per year | Return interval |
|---|---|---|---|---|
| | *- - - - Hectares - - - - -* | | | *Years* |
| Ponderosa pine | 2,545 | 503 | 0.09 | 106 |
| White fir | 20,291 | 8,615 | 2.02 | 49 |
| Red fir | 32,828 | 4,234 | 0.06 | 163 |
| Jeffrey pine | 20,095 | 2,668 | 0.06 | 158 |
| Lodgepole pine | 63,664 | 2,306 | 0.02 | 579 |
| Whitebark pine | 26,091 | 26 | 0.00 | 21,073 |

with the private sector can overcome deep-seated resentments often present when local economies are dependent on parks and wilderness. Much needs to be done in all of these areas.

Perhaps the greatest opportunities for allowing natural fires to play their role in wilderness ecosystems will come from the realization that to do otherwise will only lead to future catastrophes.

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# Fire Management in Small Wilderness Areas and Parks

**Susan J. Husari**

**Abstract**—Appropriate wilderness fire management balances the requirement to provide fire protection and the need to allow fire to play its natural role in wilderness. Geographically small areas present special management problems because of the immediate risk of escape of fires. Comparison of the scale of fire to the size and characteristics of the area can assist managers in devising an appropriate mix of fire suppression, prescribed natural fire, and planned prescribed fire for small areas.

All wilderness fire management programs incorporate fire suppression. Wilderness fire management programs may also include prescribed natural fire or planned prescribed burning. Appropriate wilderness fire management is a balance between the practical considerations of fire protection and the need to allow fire to play its natural role in wilderness. This paper explores the problems associated with establishing programs in small wilderness areas and parks and offers a framework for solution development.

## WHAT IS A "SMALL" AREA?

One must look beyond the concept of wilderness area size to assess whether an area is "small" or "large," in the context of fire management. A comparison of the potential scale of fires to the scale of the area can help give perspective as to whether a wilderness area is too small to consider use of a particular fire management strategy. Managers must be mindful of the fact that wilderness boundaries have been established for a variety of administrative reasons, and these boundaries may or may not make sense from an operational fire standpoint.

One way to select fire management strategies for wilderness is to compare the characteristics of fires within the area with the attributes of the individual wilderness area.

The following fire and weather characteristics should be examined:

- Typical fire size during normal conditions.
- Typical fire size during drought conditions.
- Typical fire event duration.
- Frequency of extreme fire weather.
- Fire behavior: rate of spread, intensity, spotting, crowning, and duration of fire.
- Variability in fire cycle.

The fire and weather characteristics are then compared with the following attributes of the area:

- Shape of area.
- Defensible boundaries.
- Natural barriers.
- Size of area.
- Elevation gradient.
- Orientation in relation to weather patterns.
- Fuel continuity and distribution within the area.

## CASE STUDIES

The following case studies discuss site-specific variables important to the management outcome of wilderness and park fire management programs. Fire characteristics and area scale are displayed for six management areas.

### Case 1

The fuel patches in the management area are divided into discrete units by nonflammable vegetation or natural barriers such as water or rock. Fires do not spread out of or into the management area. One example (table 1) illustrates the program type.

### Case 2

The fuel patches in the management area are divided into discrete units by nonflammable vegetation or natural barriers such as water or rock. Fuel continuity decreases with elevation. Fires either originate in the fuel patches and consume them or burn into the area from more continuous fuels in lower elevations. Two examples (tables 2, 3) illustrate this program type in different sized areas.

### Case 3

Fuels are continuous within the wilderness area and across the boundary of the wilderness with adjacent lands. Fires initiate and spread quickly. Fire history includes fires that are larger than total size of the wilderness area. Two examples (tables 4, 5) illustrate this program type from areas of very different size and fuel type.

### Case 4

The area contains a combination of fuel/vegetation types with different fire regimes. Fuels at lower elevations are continuous, but become more patchy as elevation increases. Fires may initiate slowly but move rapidly when affected by high winds. One example (table 6) illustrates the program type.

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In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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**Table 1**—Fire history data for Everglades National Park, Fire Management Unit I, National Park Service (Everglades National Park Fire Management Plan 1991)

| | |
|---|---|
| Area size | 401,225 acres |
| Period of record | 1948-89 |
| Lightning fires | 141 |
| Human-caused fires | 96 |
| Average fire size | 206 acres |
| Largest fire | 5,600 acres |
| Fire behavior | Fast-moving fires in grass type. Fires burn for a maximum of two to three burning periods before running out of fuel. |
| Influence of suppression | Little or none. Direct suppression action is impossible. Fires have always burned to natural barriers and self-extinguished. |
| Other influences | Exotic plant invasion and changes in freshwater input to system due to upstream water management. |

**Table 2**—Fire history data for Emigrant Wilderness, Stanislaus National Forest, Pacific Southwest Region, Forest Service (Emigrant Wilderness Fire Management Guide 1993)

| | |
|---|---|
| Area size | 112,000 acres |
| Period of record | 1972-90 |
| Lightning fires | 72 |
| Human-caused fires | 52 |
| Median fire size | Less than 1 acre |
| Largest fire | Class C (10-100 acres in size) |
| Fire behavior | Low- to moderate-intensity fires burning in timber litter. |
| Influence of suppression | Suppression action taken on all fires except those that were managed as prescribed natural fires between 1978 and 1987. Fires that would have been 1 to 100 acres in size have been replaced by fires less than 1 acre in size. Movement of fires into the wilderness from the mixed conifer and red fir zone has been limited due to fire exclusion. |

**Table 3**—Fire history data for Granite Chief Wilderness, Tahoe National Forest, Pacific Southwest Region, Forest Service

| | |
|---|---|
| Area size | 24,600 acres |
| Period of record | 1960-90 |
| Lightning fires | 74 |
| Human-caused fires | 13 |
| Median fire size | Less than 1 acre |
| Largest fire | Less than 10 acres |
| Fire behavior | Low- to moderate-intensity surface fire in timber litter. Fires burn until fuel patches are consumed. |
| Influence of suppression | Suppression action taken on all fires. The result has been replacement of fires in the 1- to 100-acre range with fires less than 1 acre. Movement of fires from areas outside the wilderness has been prevented by fire exclusion in the mixed conifer and red fir zone. |

**Table 4**—Fire history data for Pinnacles National Monument, Western Region, National Park Service (Greenlee 1981)

| | |
|---|---|
| Area size | 13,270 acres |
| Period of record | 1931-79 |
| Lightning fires | 1 |
| Human-caused fires | 61 (30 are prescribed burns) |
| Median fire size | Class C (10-100 acres) |
| Largest fire | 25,000 acres |
| Fire behavior | Crown fires in chaparral and brush. Natural barriers do not impede fire spread. |
| Influence of suppression | All unplanned fires have been suppressed. The area also has an active prescribed burning program. Few natural ignitions have been recorded. Prior to fire suppression the fire regime was probably dominated by large fires that burned into the area from outside. |

**Table 5**—Fire history data for Everglades National Park, Fire Management Unit II, Southeast Region, National Park Service

| | |
|---|---|
| Area size | 419,000 acres |
| Period of record | 1948-89 |
| Lightning fires | 221 |
| Human-caused fires | 271 (includes 128 prescribed burns) |
| Average fire size | 1,166 acres |
| Largest fire | 99,000 acres |
| Fire behavior | Fast-moving grass fires. |
| Influence of suppression | Fires have been suppressed under drought conditions. Fires that would have burned into the area from the exterior have been reduced in number. |
| Other influences | Exotic plant invasion and changes in freshwater input to system due to upstream water management. |

**Table 6**—Fire history for the San Gabriel Wilderness, Angeles National Forest, Pacific Southwest Region, Forest Service

| | |
|---|---|
| Area size | 38,118 acres |
| Period of record | 1970-91 |
| Lightning fires | 21 |
| Human-caused fires | 40 |
| Median fire size | 1-10 acres |
| Largest fire | 50,000 acres in 1924; 24,000 acres in 1957 |
| Fire behavior | Crown fires in chaparral and brush at lower elevations. Low- to moderate-intensity surface fire in upper elevation timber stands. Large fires burn under the influence of Santa Ana winds. |
| Influence of suppression | All fires have been suppressed. |

In comparing the six areas, it is apparent that the geographic size of the area has little to do with the utility of use of prescribed natural fire. The largest area, FMU II in Everglades National Park, is one of the smallest operationally, as the scale of fire compared to the size of the management area indicates. Fires can ignite and spread rapidly to the management unit boundary within several days. The Granite Chief Wilderness, at 24,600 acres, just 5 percent of the size of FMU II in Everglades, is actually quite large when the potential fire size is compared to the total area.

## SELECTING MANAGEMENT STRATEGIES

The size of the wilderness area or fire management unit is not relevant where fuels are divided into discrete patches by natural barriers. Prescriptions for prescribed natural fire programs can be sufficiently broad-based to incorporate much of the natural fire regime. However, changes in fire behavior, spotting, and fuel availability during drought must be considered and prepared for accordingly. Vegetation type or barriers that arrest fire spread in normal years may not impede fire spread in extremely dry years.

Selection of fire management strategies in areas with continuous fuels requires additional analysis. Several management options are possible if fire history indicates that fires greater than the size of the management area are common events. First, a suppression-only policy can be implemented. Second, predetermined holding actions can be implemented as part of the prescribed natural fire program. Holding actions are most practical in fuel types where fires grow slowly in the initial stages. Third, prescribed burning or other fuel treatment can be used to treat area boundaries to create barriers to fire escape. This is applied where fires initiate and grow rapidly. In areas where the creation of defensible boundaries is not feasible, planned prescribed burning may be substituted for natural prescribed fire.

Situations exist where either models or common sense indicate that fires have the potential to leave the area, even when fire history shows otherwise. In such cases additional analysis of the probability of escape is needed. The probability that weather events will cause fires to exceed prescribed limits prior to extinguishment by rain should be determined. Wiitala and Carlton (1993) provide a method for analyzing the risks associated with long-term fire movement. This method is designed for assessing fire movement within large wilderness areas with continuous fuels. It displays the risk that the fire will leave a defined area prior to the end of the fire season.

## NATURAL FIRE REGIMES

The concept of ecological scale is also relevant to wilderness fire management. Most wilderness areas are not large enough to be influenced by the full range of natural disturbances typical of large-scale ecosystems (Christensen 1991). Several questions should assist in determining what portion of the original fire regime can function within the boundaries of a park or wilderness area.

- Are enough natural fires ignited within the area to duplicate the natural fire regime?
- Was the original fire regime characterized by fires burning into the area from the exterior?
- How much has the fuel complex changed during the period of fire exclusion?
- Have fuel complexes and fire behavior changed due to other forms of disturbance? Examples are exotic plant invasion, changes in hydrology, or air pollution.

Five of the wilderness areas described in tables 1-6 are small from an ecological perspective, since none includes the full range of natural disturbance. The lone exception is FMU I in Everglades National Park, an example of a self-contained fire regime. It is not immune, however, to outside disturbances that have indirect impacts on the timing and frequency of fire occurrence. The areas are no longer impacted by large-scale, long-duration fires that burned over vast areas and were an important part of the original fire regime. This is compounded by the political, social, and economic constraints on the application of prescribed natural fire within wilderness areas.

## CONCLUSIONS

Both ecological and operational scale must be considered in planning fire management strategies for wilderness areas and parks. Most wilderness areas are "small" when potential fire size is considered in light of area attributes.

A portion of all natural ignitions is suppressed for operational, safety, financial, social, or political reasons. A combination of appropriate fire suppression, planned prescribed burning, and prescribed natural fire is therefore needed to meet the Wilderness Act objective of allowing fire to play its natural role in parks and wilderness.

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# Agency Planning Considerations are Critical

**Ron Coats**

Agency planning processes are critical to determining when and where fire is used as a management tool, not only management-ignited fire, but prescribed natural fire as well. Fire use must be linked to program management objectives, not just to arbitrary thoughts or decisions to put fire on the landscape or to allow fires to burn.

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Some considerations that must take place during the planning process are: link to resource management objectives, integration with neighboring landowners, effects on our publics, integration with other functional areas, definitions of desired future conditions, and so forth. Some other items that are just as critical include agency commitment to meeting goals, a unit's capability of success, and consideration of other viable options to burning.

Planning is not fun, but it is a must if we are to continue our use of fire, which happens to be the only "natural" disturbance process that we can attempt to manage. The intent of our panel is to discuss the important aspects of the planning process.

# The National Park Service Program

## Rod Norum

The National Park Service objective for fire in wilderness (and parks managed as wilderness) is to include, to the fullest extent possible, fire as a natural, accepted, and irreplaceable functional factor in the proper management of natural systems.

We work within constraints. We sometimes work with ethics, beliefs, biases, preferences, and viewpoints which are very hard to define and sort out, and which have every potential to be in conflict. We work within laws, including those that protect resources such as quality air, or species that are rare or in jeopardy of being lost. We are not exempt from other laws that permit us to be sued if we cause harm, loss, or even pronounced offense to others. We seek to keep fire functioning in that elusive "natural" manner as we find our way through the maze of resource objectives, visitor protection obligations, cultural resource protection, and the impact of wildfires that force us to quickly adjust all of these and evaluate things anew.

It can, frankly, become a thankless task because of the surprisingly diverse opinions about what is natural and therefore permissible, and other opinions that simply disagree with the whole idea as irresponsible; an abdication of all responsibility.

The solution and salvation of the whole program of natural fire in parks is to look past the interesting, but fruitless philosophical overviews and concentrate on individual cases; single parks with their own individual personalities of vegetation types, topographical attributes, fuels mosaics, cultural resources, climate, neighbors, typical fire behavior, current status, size and shape, founding legislation, previous management, and many other things. Parks are designated because they are not ordinary places. They most often are not even representatives of commonplace things. Parks are parks, usually because they are very special, unique places. That's what makes them wonderful. It is also what makes them extremely hard to manage and to write policy for.

We can and do espouse a national attitude of favoring the most liberal and untouched natural fires possible in parks. The true, actual, meaningful policy and practice is designed and carried out at the park level, simply because of the unique character of each park and the need to tailor fire practices to suit the unique needs of each special park. This in no way suggests that there is not strong, enforced, required national policy guiding the options and requirements to be followed as park fire management plans are developed to serve the special needs of the park ecosystems. Standards of management for any prescribed natural fire are the same nationally, and are driven by the recommendations of the Final Report on Fire Management Policy of May, 1989. Personnel qualifications are set to the same high standards, regardless of the location, size or the potential of the fire. Monitoring, fire behavior forecasting, contingency plans, and approval documents are required for every day of the life of a fire. However, the prescriptions for fires are special, individually developed decision tools which are different for every park in order to manage each fire for the best interests of each special ecosystem. Clearly, prescriptions for the mountains of Yosemite will not be remotely like those appropriate for the Everglades or for Isle Royale up in Lake Superior. Parks are developed for special attributes, so vegetation, wildlife, natural features, cultural treasures, and other things will determine what will be emphasized in fire prescriptions and plans for a park. The relationships with neighbors and neighboring agencies, along with their land management imperatives, determine how cross-boundary agreements will be structured. Practice is defined at the local park level, with operational guidance and oversight by the regions.

So, national policy guides, sets standards, reporting requirements, funding procedures, daily management procedures, and personnel qualification standards to manage prescribed natural fires. Individual, reviewed, approved park fire management plans spell out the special times, conditions, and constraints for prescribed natural fires, tailored for the individual parks.

To set high standards, to embrace highly ethical philosophy, and to seek to give ecosystems the very best everywhere in the nation, are all laudable attitudes indeed. To roll up your sleeves and get right down to properly managing individual fires at special parks is a much harder, knottier problem. You can dream of perfection, which cannot be achieved, or you can strive for excellence, which can be achieved and maintained by vigorous and continued effort by professional people who really care. We've opted for the latter. We've aimed for excellence in our natural fire program as we've picked up the pieces after 1988. We don't presume to boast about success, but neither are we shy or embarrassed by it. We are simply grateful that we have had the opportunity to bring a vital, absolutely necessary, fully functional program of prescribed natural fire back into responsible operation in the National Park Service.

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# Planning for Desired Future Conditions in Wilderness

**Jerry Stokes**

As forest plans are implemented and revised, attention is being given to the adequacy of direction provided for wilderness management. Most forests will be amending their plans to provide additional direction for wilderness as a result. This process offers the opportunity to specifically define the desired future conditions for wilderness ecosystems, including the role of fire—providing the basis for direction, guidelines, and standards for management of fire. The recent round of Prescribed Natural Fire plans could be amended or (where appropriate) developed as part of this forest plan refinement. Where smoke may affect public health, a greater emphasis on the use of planned ignitions may be required.

The new emphasis on ecosystem management in this round of planning makes the completion of wilderness planning critical to adequately defining the management that will be needed to maintain the resource.

The forest health initiative will also result in forest plan amendments. The ecological approach under consideration emphasizes prescribed fire. Because of the landscape scale dictated by forest health issues, prescribed natural fire in wilderness must be part of any management strategy. Wilderness goals must be adequately considered in this process, and the desired future condition for forest health must be appropriate in wilderness.

In addition, issues must be addressed regarding effects to air quality from prescribed fire (both inside and outside wilderness). The goal for fire in wilderness must be considered when addressing these issues—for example, it will be necessary to define "natural" fire regimes for wilderness and the corresponding "natural" smoke. Our expectations of pristine, clear air may need to be reevaluated, based on the management needs of fire-adapted ecosystems in class I wilderness.

The new round of planning is the opportune time to add the considerations of the effects of air pollutants on wilderness ecosystems. For class I wilderness, the Air Quality Related Values have already been identified. Where these are general wilderness or resource values, they may be included for class II areas as well. This could be the time to resolve our expectations of the impacts of other activities on National Forest ecosystems, as we assess the impacts of our proposed activities on them.

Other related issues include consideration of pesticide use in wilderness and treatment of fuels in wilderness in order to reduce fire risk to adjacent lands.

Wilderness management and prescribed natural fire are also linked to the ongoing issues and actions related to spotted owl habitat and other threatened and endangered species habitat management (both animal and plant). An expanded desired future condition for wilderness must include goals for threatened and endangered species—this desired future condition would, in many cases, provide additional direction regarding prescribed natural fire and management of threatened and endangered species habitat in wilderness.

Performance elements for the regional forester, directors, and forest supervisors now include an element for wilderness program management. The standard for wilderness emphasizes (among other things) wilderness planning, improved integration of wilderness management with other Forest Service programs, and increasing attention to wilderness ecology. The opportunities discussed here offer an ideal path to demonstrate a commitment to meet the challenge of this new performance element.

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# U.S. Fish and Wildlife Service Wilderness Planning Considerations

Bill Leenhouts

The U.S. Fish and Wildlife Service manages 75 units of the National Wilderness Preservation System totaling 20,676,342 acres (Figure 1). The service is second only to the USDA Forest Service in the number of units under agency stewardship. The Service manages the second largest and the smallest wilderness areas within the National Wilderness Preservation System: Arctic (8,000,000 acres) and Pelican Island (6 acres). All but one of the wildernesses are part of the National Wildlife Refuge System. The exception is on a National Fish Hatchery (USDI FWS 1993).

Although the largest acreage of wilderness is in Alaska (18,676,320 acres), most of the units are in the lower 48 states. Many are smaller eastern units located near major metropolitan areas. A majority of the units are wilderness islands or are wetland dominated ecosystems.

## WILDERNESS AND FIRE PLANNING POLICY

Wilderness areas are planned and managed as part of the entire Service land unit with appropriate management to comply with the Wilderness Act, and in Alaska, the Alaska National Interests Lands Conservation Act. The Service has long recognized that ecosystems and their components do not recognize administrative boundaries. Therefore, a holistic management strategy is applied to the Service land unit where wilderness has been designated, or where an area has been identified as a study area or recommended for inclusion within the Wilderness Preservation System.

Wilderness areas on Service lands are managed to preserve, to the extent practicable, the interaction of natural forces with the land using the minimum tools necessary to safely accomplish the Service's mission. Management activities in wilderness areas are planned and carried out in conformance with the Wilderness Act's purpose of securing "an enduring resource" of an area essentially "untrammeled by man" where natural ecological processes operate freely and the area is "affected primarily by the forces of nature." Service activities must be compatible with the purposes for which the Service land unit was established, the goals of the respective Service lands system, and the objectives of the individual unit.

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When a Service wilderness area is contiguous with other federal lands, the Service remains the active manager of the land, unless it is determined that more effective wilderness management can be achieved by some form of cooperative management. Cooperative planning is essential, and joint management plans with all involved agencies are encouraged.

The planning process must integrate wilderness management objectives with establishment purposes, system goals, and unit objectives. Service planning conforms to a cyclic incremental approach (Figure 2). Each Service unit must develop a Comprehensive Management Plan to guide management decisions. The Comprehensive Management Plan consists of background information, analysis, unit objectives, long-range management strategies and applicable operational plans. The operational plan deals with a specific management subject (such as marsh and water management, wilderness management, fire management, or public use management).

Every unit with a designated wilderness is required to develop a Wilderness Management Plan. The Wilderness Management Plan, a step-down plan, guides the preservation of the area, setting out the relationship between wilderness management objectives and the purposes for which the unit was established, system goals, and unit objectives. The plan also establishes indicators, management actions to reduce or prevent impacts on the wilderness. The plan is developed with public involvement and contains specific, measurable management objectives that address the preservation of wilderness-dependent cultural and natural resource values in order to achieve the public purposes of the Wilderness Act and other appropriate legislation. The limits of acceptable change process is used in developing the Wilderness Management Plan for both recreational and natural resource management purposes. Wilderness monitoring and evaluation criteria are identified during the LAC process.

Every unit with vegetation that can sustain fire is required to develop a Fire Management Plan. Wildfire suppression standards and prescribed fire use within the wilderness must be addressed in the Wilderness Management Plan with operational aspects addressed in the Fire Management Plan. Control, containment, or confinement are appropriate wildfire suppression responses; the appropriate response is determined by considering the least-cost options and the values at risk. The minimum tool concept is a guiding factor in determining the appropriate strategy. Natural and management-ignited prescribed fire may be used to meet specified wilderness or resource management objectives.

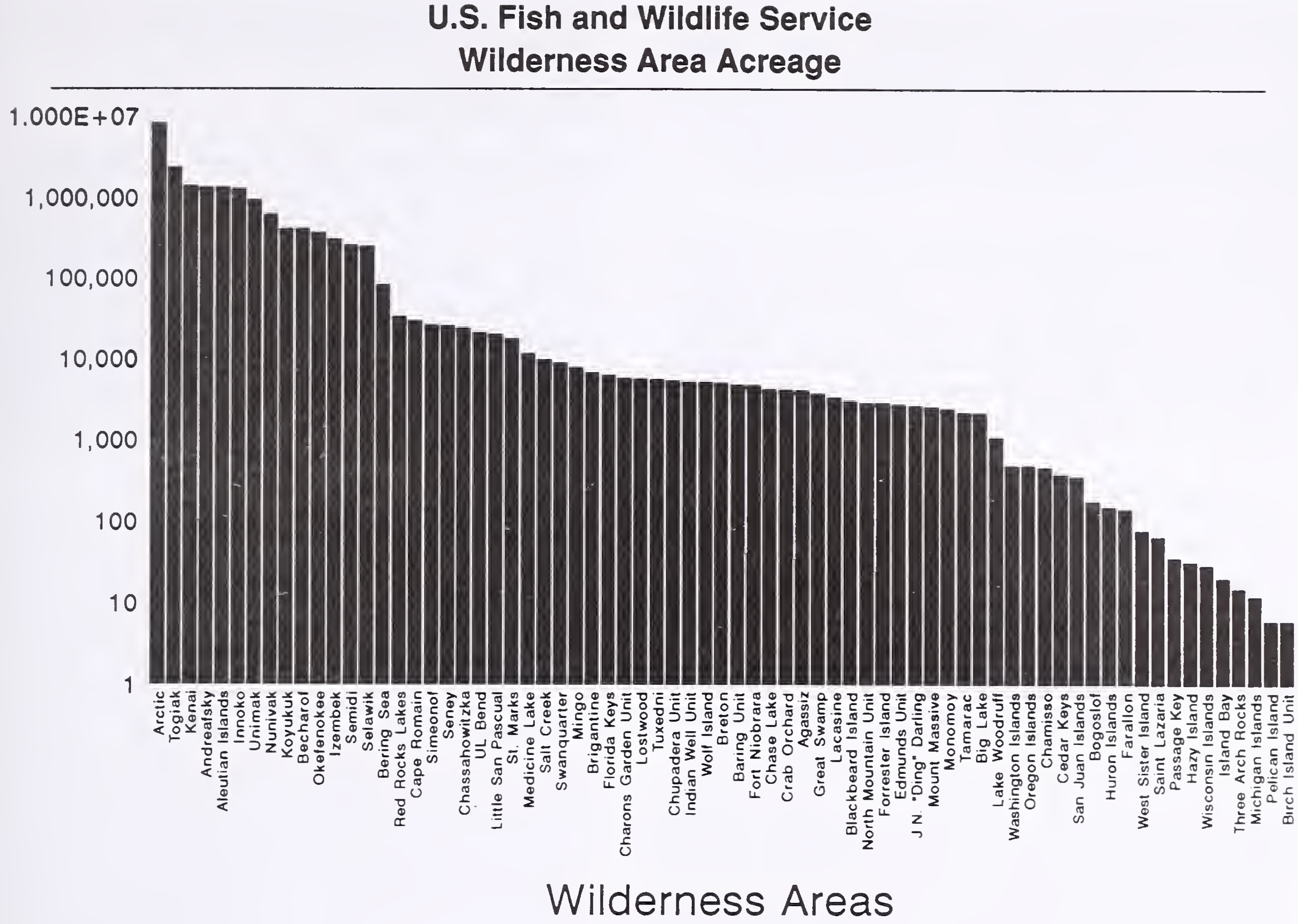
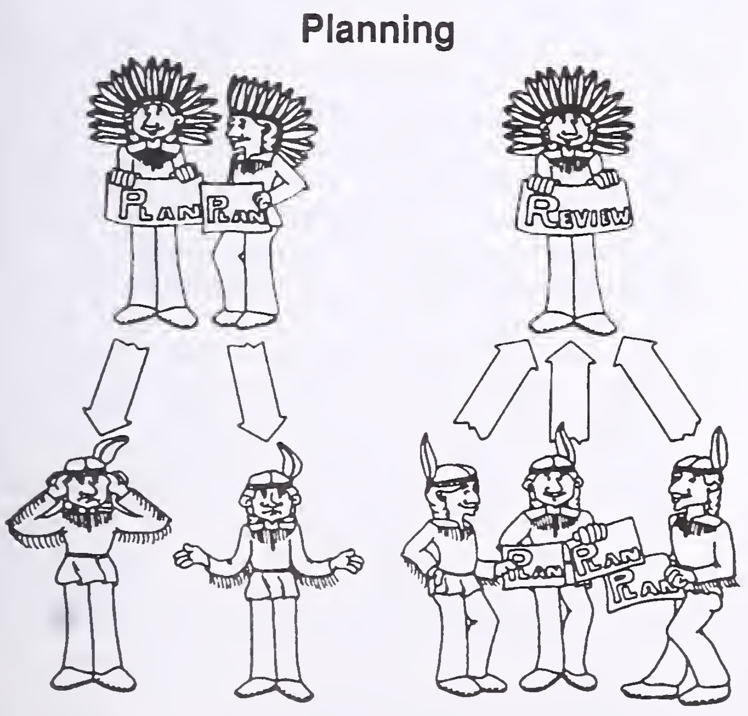



Figure 1




Linear-Comprehensive Management

Cyclic-Incremental Management

Figure 2

## THE CURRENT SITUATION AND FUTURE PERSPECTIVES

Fire is an ecological process in many of the Service's wildernesses. Most Alaska wilderness areas are in the interagency limited suppression land use category and the containment suppression strategy is used. Fire as an ecological process remains relatively intact in Alaska.

The Service has no prescribed natural fire plans for any unit, and opportunities for prescribed natural fire are quite limited. The containment strategy is frequently used in Service wildernesses to suppress wildfires because it is the least costly suppression strategy with some ecological benefits accruing.

The objective of prescribed natural fire is to produce natural fire patterns from lightning ignitions. The objectives of most Service land units generally focus on enhancing some particular wildlife resource. Management-ignited prescribed fire or some other resource management activity has greater utility in achieving these objectives than does prescribed natural fire.

The Service has an active management-ignited prescribed fire program, burning an average of 160,000 acres per year, more than any other Department of the Interior

bureau. Minimum impact management-ignited prescribed fires are frequently used within Service wilderness areas in order to achieve specific unit objectives. These management-ignited prescribed fires supplement the ecological process of natural fire. With emphasis on natural process management, these activities are projected to increase by 30 percent by 2003 (USDI FWS 1993).

The Service's greatest management challenge for maintaining natural ecological processes operating freely is in our wetland ecosystems. Many of these systems require extremely long duration peat fires at fire return intervals of 100 to 200 years during drought cycles when surrounding uplands are in extreme fire danger (Hermann and others 1991). The probability of our customers accepting the consequences (potential escapes, smoke, health, and safety risks) of such fires is extremely low.

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# Public Involvement in Wilderness Fire Planning and Decision Making

**Elayne M. Murphy**

**Abstract**—Public involvement is crucial to the success of any prescribed natural fire program. Unfortunately, it is a job that few fire managers are comfortable doing. This paper highlights some of the attitudes that keep agencies from doing good public involvement. It also features some of the key approaches in developing a public involvement plan.

I am the public affairs specialist for the Nez Perce National Forest, and I have to say I have one of the best jobs in the Forest Service! One of my favorite tasks is a local radio program called "Talk About the Forest." It is a 3- to 5-minute discussion about a topic of interest that is aired twice a week on KORT, our Grangeville radio station. If there is a challenge in doing this program, it is finding a constant supply of guests for my assistant or myself to interview. When we ask people about participating, we get a range of responses from an enthusiastic "I'd be glad to do the program," to a more cautious "I'm interested, but I'm not sure about how I'll sound on the radio." For purposes of this talk, I would like to focus on the most unique and definitive response I have ever gotten: "Elayne, I'd rather crawl through a culvert naked!"

How do you feel about public involvement? Do you greet the challenge enthusiastically or would you rather "climb through the culvert naked" than plan and implement a public involvement program?

## THE TWO A'S

When I joined the Forest Service 10 years ago, I have to admit most of what I knew about fire I learned from the Smokey Bear school of fire management. It did not take me long to realize fire management was much more complicated than just putting out fires. As a matter of fact, just putting fires out could be a complicated process. From the Gary Meyer and Dave Poncin schools of fire management, I learned about the three C's of fire suppression: confine, contain, and control. Today, I am not going to visit with you about these three C's. Instead, I am going to visit with you about two A's important to public involvement: attitude and approach.

These thoughts did not come from research and models. My comments are based on observation and intuition after 10 years "in the trenches" working for forests with substantial prescribed natural fire programs.

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### Attitude

I would like to begin my discussion of attitudes that are hindering our public involvement efforts by focusing on fear—the thought that you would rather "climb through the culvert naked" than plan and conduct public involvement programs.

I am not here to chastise you for feeling fear, but to say I understand it! We are dealing with a complex program, a society that is increasingly interested in forest management, and interest groups that are very polarized in their views about prescribed natural fire.

If you are one of these people who fear public involvement, you must be willing to take a risk. You can be effective only if you step out of your comfort zones and work with people as part of your prescribed natural fire jobs.

The second attitude I would like to address is the "it's-not-my-job syndrome." I cannot speak for other agencies, but in the Forest Service there is a lot of finger pointing occurring. The truth is we all share in the responsibility.

From the national level, we need an education foundation on which to build. The prescribed natural fire message needs to be heard nationwide, and I do not have the means in Grangeville, ID, to influence national opinion. Why can't prescribed natural fire have a national program that complements Smokey? At the very least there must be close coordination with Smokey campaign managers, so Smokey is not delivering messages that are inconsistent with the prescribed natural fire program.

Regionally, there is a second role. Public opinion in Missoula, MT, and Boise, ID, is going to influence north-central Idaho prescribed natural fire programs. Most forests cannot reach these larger cities without a regionally coordinated campaign that focuses on the "big" prescribed natural fire picture.

Locally, fire managers have to embrace public involvement as part of their jobs. The forest's public affairs officer cannot be the public's sole proponent, nor can the public affairs officer have his or her fingers in all the public involvement work going on at the forest level.

So what can public affairs personnel, such as myself, do? We can support your efforts through advice, media work, facilitating public meetings, and even sharing our thoughts and perspective at a conference such as this.

By the way, I have to put in a plug for my coworkers and fire managers on the Nez Perce and Clearwater National Forest staffs. They are conscientious and do excellent work in the public involvement area!

If you're still wondering "Why me? Why is it my job?," I'd like to leave you with these thoughts. You—all of you—are the subject-matter experts. You have the key contacts necessary to do the coordination. Most important,

you have a passion for the topic. Harness these strengths and do the job.

A third attitude that gets in our way is the belief that we know best and people would agree with us if they were only better educated.

Again, my perspective is rather limited, but I believe we are not giving people enough credit for the awareness they have. Just last summer, as I masqueraded as Smokey Bear at a children's gathering, a man came up to me shaking his finger. "Smokey, it's all your fault," he said. "Because of you we had the Yellowstone fires. Because of you forest health is declining." "Now what are you going to do about it?" he asked as he crouched down to try to look up through the nose of the costume to see who was inside.

That happened in Grangeville, ID. The man involved was a not a Forest Service employee. Our message is getting out. As a matter of fact, I recently facilitated a series of public meetings about the Gospel Hump Wilderness Fire Management Plan and the comment I most often heard was: "Why are you confining the use of prescribed natural fire only to the wilderness?" For those of you familiar with Idaho, these comments came from Grangeville, Riggins, and Dixie—rural communities where I expected stiff resistance to a change in fire policy.

Is our job done? Absolutely not. We need to raise people's awareness levels while raising our own sensitivity levels. Education is a two-way process. Take the clearcutting issue. How much energy did we spend "educating the public" about the necessity of this practice? If we would have listened to people carefully and tried to understand their value systems, we would have realized "education" about this management practice was only part of the solution. The second part of the solution was modifying our own management practices.

So what is the answer? At this conference, we have heard about "interactive public involvement." This means our role is bigger than education. It is facilitating a dialogue between all the interests and finding common ground and workable solutions.

The final attitude I would like to discuss deals with "doing things right" versus "doing the right thing."

When the Forest Service has a proposed project, employees are required by the National Environmental Policy Act (NEPA) to do a certain level of public involvement. I will not quote manuals to you; rather I will tell you I do know that some people do just enough public involvement to meet those procedural requirements and not to gain new information or meaningful input from the public.

To do the right thing—to design and implement a meaningful public involvement program—is hard work. It requires time and often painful discussions. The results are worth the effort! What results am I talking about? I am talking about better decisions, better informed publics, and a solution that can be implemented.

So how do I determine what is the "right thing to do?" There is no cookbook, but there is a series of choices that need to be made. This brings us to the second "A"—approach.

## Approach

Fire behavior and public behavior are similar in that they are not very exacting sciences. The other similarity they have is if you're not careful, you can get burned!

What I am going to suggest is a thought process you can use to develop a public involvement plan; to use fire terminology, it can be considered as a "prescription." I suggest you evaluate my thoughts, tailor them to meet your needs, and realize there is much more complexity than I have time to discuss.

Building a public involvement plan for a project is something any of you can do, but you cannot do it alone. The first step I would suggest you take is to sit down with the decision maker and decide what the goal of your public involvement effort is. There is a spectrum of options from which to choose. At one end of the spectrum is "inform," somewhere in the middle is "involve," and at the other end of the spectrum is "building consensus." All options are acceptable depending on the scope of your project, the environment in which you are operating, and anticipated future needs.

Let's talk about the "inform" end of the spectrum. In all likelihood, this will take the least time. For the most part, the dialogue is one-way, so you would not get a sense of what the public is thinking. Since you are not seeking a lot of participation, you probably will not get it. Consequently, there will probably be little buy-in for your project once the analysis is completed.

On the other end of the spectrum is consensus building. This is messy stuff! Bringing all the interests together and facilitating a dialogue that leads to a decision that everyone understands and supports is time consuming and sometimes impossible. The payoffs are great if it can be done.

My sense is that you will be somewhere in the "involve and build relationships" portion of the spectrum when choosing the goal for your prescribed natural fire public involvement plan. The key is to make a choice with your manager and let that guide your process.

Another step you will want to take early in the process is to identify your potentially affected interests. Who are these people? They are anyone who is potentially affected or interested, internally and externally. For instance, when developing the Gospel Hump Wilderness public involvement plan, we had a brainstorming session and listed adjacent landowners, outfitters and guides, local opinion leaders, cooperating State agencies, specific Forest Service employees, communities that could potentially be affected by smoke, and the list goes on and on.

Two other questions you might want to ask yourself to help focus your efforts are: "Who can aid in implementation (potential partners)?" and "Who can block implementation?" You cannot ignore this opposition!

What about the general public? You try to get them involved realizing they are already overcommitted and overcommunicated. In the real world few will choose to participate, and the majority of your efforts will be focused on the potentially affected interests.

Once you determine goals and a target audience, it is time to consider the tools available. You have too many options to discuss today, so I would like to suggest a starting point: Talk to your public affairs officer about the types of public involvement tools that have been successful in the past.

At the Nez Perce National Forest, we recently had an integrated program review. As part of that review, our key contacts were asked, "How do you like to find out about public involvement opportunities?" Their responses: 90 percent said direct solicitation (scoping letters, phone calls); 43 percent identified a "newsletter" as their preferred source (worth noting since we don't do a lot of newsletters); and 33 percent said through the newspapers.

Since newspapers were mentioned, I have to digress here to talk about working with the media. If there is one piece of wisdom I can leave you with today it is this: Get to know the media contacts in your area. Develop good working relationships. If you wait until there is a crisis, it is too late.

One of our successes for the Nez Perce and Clearwater Forests was a little get-together called "Fire and the Media." We held this for north-central Idaho reporters in May of 1989 so we could have a dialogue about Yellowstone and the status of the prescribed natural fire program in our area. We shared information about prescribed fire and wildfire and even gave reporters glossaries of terms and copies of shift plans. To this day, I believe this effort has paid off in big dividends because reporters are interested in prescribed natural fires (not to the same degree as wildfires, but there is interest) and their reports are fairly accurate.

I would like to talk a little more about working with the media because not everyone understands the basics of media operation. It is important for you to know that news about your fires or programs competes for space with all the other news of the day. When you write a news release or feature story, there is no guarantee it will be printed. The exception will be most weekly papers because they are short staffed and cannot get out to cover as many news items as they would like. Daily newspapers, as a rule, will rewrite your press releases and will throw out your feature stories. They have reporters and photographers to do their own work. In that instance, your challenge is to entice the reporter to use your news release or write your feature story. Your success will depend on the new angles you can give to the topic of prescribed natural fire.

Remember: There are no guarantees you will like what is written. Reporters are supposed to be objective and to present all points of view. What started in your mind as a positive feature story may take some unexpected twists and turns.

So what can you do to get your messages out? Paid ads are an option that gives you total control. The government is allowed to purchase ads for information purposes, not promotion. This is a fine line you will need to consider. A second option is the "Letter to the Editor." If you meet a newspaper's criteria, your letters will be printed as written, and they will appear in a section that is often one of the most-read parts of the paper. Finally, many papers accept guest editorials. If you have a message and want visibility and control, this may be another option.

Media is only one tool of the multitude from which you can choose. You can do direct mailings, newsletters, small meetings with key players, public meetings, etc. There are special courses available to teach you about these tools. Choose to take one of them in the future.

Choice of a tool is important, but so is how you use it. Newsletters can be effective only if people are enticed to read them. Slide-tape programs are only effective if people can understand them. I cannot complete a discussion about public involvement without some thoughts about effective communications.

## EFFECTIVE COMMUNICATIONS

Fire management is complex. It is a very specific science with its own jargon, and that jargon is constantly changing. That is not helping our public involvement efforts. Recently at a public meeting, one exasperated participant told us he understood prescribed fire before Yellowstone. Now we talk about prescribed natural fires. He asked us to consider the use of the term "let burn" because that best described the program. I know that causes many of you heartburn. Like it or not, "let burn" is a phrase that is not going away. Let's embrace it and define it for people.

I would like to offer some suggestions that will help you make your papers or talks more understandable. This advice was given to me by a local newspaper editor. He said: "Elayne, if you want to write in a manner that the people of Grangeville can understand, spend an afternoon at Brown Motors and listen to the talk that occurs over the counter. Then write your press releases using those words."

Brown Motors sells and services heavy equipment. Their patrons are hard-working, intelligent people. But they aren't wrapped up in the day-to-day business of forest management. Consequently, many agency terms and jargon do not have any meaning for them.

So how do we communicate with the patrons of Brown Motors? We break complex concepts down into easy-to-understand words, analogies, and anecdotes to which people can relate. Yesterday, Dave Bunnell talked about a fire "pooping around." The public is much more apt to understand that description than that of a "nonlethal, low-intensity ground fire."

The more senses people can use, the more they will learn and understand. Conduct your discussions in the forest where people can hear your talk, see the influence of fire, and touch the ground and vegetation. When that is not possible, use maps, photos, video, and even vegetation samples so people can have visual and tactile experiences.

Finally, you must interject an emotional component into your communication. For those of you who think science and emotion do not mix, I offer the example of Smokey Bear. Smokey's success isn't based on scientific fact; it is based on the emotion evoked by the story of a bear cub who survived a forest fire that could have been prevented.

## PLAN AND DO

Once you have thought all these things through, it is time to put together your action plan—who is going to do what by when. Another column I use is a "status" column so I can keep track of accomplishments relative to timeframes. Now put your plan to work!

While you are implementing your plan, remember: conditions change and your plan might need revising. You need to manage your public involvement effort like you do a prescribed fire with constant monitoring and validation. When the plan "goes out of prescription," take action.

Once you have implemented your public involvement plan, you will have good information to incorporate in your analysis. That ultimately leads to the decision. Many people end their public involvement here. The truth is you are not done yet!

The next step is critically important: Thank people for their input, let them know what they said, legitimize their concerns, and let them know how their input shaped your decision. What am I talking about? For instance, let's say smoke is an issue raised by the public. Tell them you—the public—said you had concerns about smoke. We do too. As a result, smoke is one of the nine key factors considered when a fire is analyzed for prescribed natural fire status.

Finally, learn from your public involvement effort. After a prescribed natural fire, you usually go back to the site. You analyze what happened. You learn from each fire. We need to do that in the area of public involvement. I am not advocating full-blown monitoring programs, but just a few phone calls to key individuals to get their reactions to your efforts and decision.

Once you get your fire management plan back on-line you have created a new need: a need for a postdecision communication plan. This action plan will help shape future information operations and will be discussed later in the conference.

## THE CHALLENGE

Would you still rather "climb through the culvert naked" than do public involvement for your prescribed natural fire programs? I hope this paper has caused you to reexamine some of your attitudes, given you the basic approach to plan and conduct a public involvement program, and made you realize public involvement does not stop once a decision is made. I challenge you to make public involvement important, meaningful, and a part of your day-to-day business.

# Public Information on Actively Burning Prescribed Natural Fires

**Jane Schmoyer-Weber**

The Canyon Creek and Gates Park fires ignited in a "remote" wilderness, far from any major population center. They differ in this respect from prescribed natural fires in areas closer to population centers, such as Yosemite National Park. The nearest communities to these two fires are 20 to 35 miles from the wilderness, and their populations average between 500 to 2,000 residents. The landscape is also unique. Mountain ridges oriented along the Continental Divide form a north-south linear boundary separating mountainous forested public lands from rolling private rangelands. A narrow, linear strip of nonwilderness National Forest land buffers the private land from the wilderness boundary. This country is commonly referred to as the Rocky Mountain Front, "where the mountains meet the plains."

The landscape configuration and remoteness of the Canyon Creek and Gates Park wilderness fires are not the only dissimilarities between these fires and prescribed natural fires in areas nearer population centers. The people affected by fires in the Bob Marshall Wilderness Complex differ from people affected by fires in a nationally recognized park, like Yosemite. While Yosemite National Park receives millions of recreation visitors from national destination points, visitors to the Bob Marshall Wilderness are predominantly Montanans. Those directly and indirectly affected by both the Canyon Creek and Gates Park fires of 1988 included not only visiting recreationists, but people who derive their livelihood from the National Forest—area ranchers, resort owners, and outfitters and guides. Unlike the Yosemite fires, public information on the two Bob Marshall Wilderness fires did not involve countless telephone conversations to assist recreationists rerouting their summer vacations. Rather, public information involved those directly impacted by these fires—those living in the local rural communities, the adjacent ranchers grazing livestock near the wilderness, the outfitters with base camps inside the wilderness, cabin owners on the perimeter of the wilderness, and recreationists who used the wilderness trails. These people lived with the mental and emotional anguish the fires caused and tolerated the physical inconveniences of these fires as they burned for over 65 days—an entire summer. The Canyon Creek fire crossed three National Forests, escaped the bounds of the wilderness and burned 240,600 acres, including 40,574 acres of private lands. The Gates Park fire remained within the wilderness, burning about 51,000 acres.

This presentation concentrates on the fire information needs of the people directly and indirectly affected by fire. I leave the discussion of techniques for dealing with the media to another topic and another day.

## OBJECTIVES

The objectives of this presentation are twofold:

- Time your fire information subject matter to meet the condition of the fire
- Tailor your public information for your publics.

## THREE PHASES FOR FIRE INFORMATION

Fire managers are not the only people who view a prescribed natural fire differently than a wildfire. The users of a wilderness and its neighbors have a personal connection to these lands, for spiritual and commercial reasons. Conflicting emotions are stirred in wilderness users and neighbors when the Forest Service monitors a fire rather than suppressing it. Fire information techniques and objectives must be tailored to wilderness users' and neighbors ties to the land and to the changing condition of the fire. To simplify this discussion, I have broken the condition of the fire into three categories:

Phase One—When a fire starts and is determined to be in prescription

Phase Two—When a prescribed fire is perceived as threatening

Phase Three—When a prescribed fire burns beyond prescription boundaries destroying personal property.

### Phase One

A fire has just started. Most likely it's small, probably producing only a whiff of smoke. Now is the time when you have the luxury of talking about ecosystem management. In this phase, people are not yet affected by the fire. Use your time wisely to discuss the benefits of prescribed natural fire, the history of fire in this wilderness, how fire moves, and how and where natural firebreaks exist. Drive home the idea that prescribed fire is managed and involves more than watching the fire burn. Choose your words carefully. DO NOT underestimate the potential of a prescribed fire, or suggest that there is no risk. You may live to eat your words.

Work closely with the Ranger District. It is critical that you begin building relationships. Find out who lives in the

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vicinity of the fire and who has a commercial operation on land near the fire. Who are the grazing permittees, outfitters, watershed managers, cabin owners, and adjacent landowners?

Many of the traditional methods of communication work during Phase One: printed flyers made available in public gathering locations, media news releases, notices posted at trailheads and trail junctions, and public get-togethers in the local library. Work with the local Ranger Districts to ensure trip adjustments for outfitters and recreation visitors are negotiated smoothly. Do not underestimate the value and future need to develop a one-on-one relationship with the key voices in the community. Any District Ranger worth his salt will know who these "key" folks are. Keep the District Ranger and the ranger's primary staffs involved in the communication efforts. You need to begin building a strong relationship with the District Ranger BEFORE fires occur. During Phase One you have extra time to strengthen relationships and enlarge the circle of relationships.

## Phase Two

When fire is perceived as threatening or when people are beginning to experience the effects of fire, you've entered Phase Two. In this phase, fire may have edged to the limits of a natural firebreak; personal property inside or on the perimeter of the wilderness may be threatened; people have been eating smoke, cattle have been moved to safer locations, and trailhead closures may have caused backcountry trips to be rerouted.

Public information now shifts gears. Break out the fire safety messages. Keep people constantly informed of the direction the fire is moving, the speed of its spread, and the actions being taken to "herd" the fire and keep it in prescription.

Don't forget to listen to complaints and do whatever you can to relieve heightened apprehension. The Smokey Bear message has been carefully taught; people fear fire. Don't allow perceptions to cloud the facts. If smoke or particulate inhalation becomes a concern, consider installing a portable particulate monitor. Arrange for local health officials to read the levels and make recommendations on exposure hazards. Remember that the people affected, whether directly or indirectly, did not choose to allow this fire to burn. We did. Accommodate their health and safety concerns and tone down discussion of the "benefits of natural fire."

Above all, do not allow the District Ranger to fade into the woodwork. It is critical that the Ranger remain up front and center. Having a stable constituency becomes increasingly more important as prescribed natural fire lingers on or moves into the next phase. Keep the Ranger in the picture. The public views the District Ranger as the person in charge. In the eyes of the public, the Ranger does not forfeit management responsibilities when an Incident Command team arrives to suppress the fire.

Emotions flare during Phase Two. Learn fast who needs to be contacted personally and repeatedly. Let people know if they need to take defensive actions for safety. At one point during the Canyon Creek fire, I was in daily, sometimes hourly, contact with the wife of a State legislator who was within days of delivering their first child. Others with critical information needs may have to remove livestock, fireproof cabins, or evacuate their homes.

Remember, you cannot do it all yourself. Assess the situation and enlist help when you need it. Be careful when recruiting assistance. While local residents can be most helpful in identifying key individuals and sensing the pulse of the community, do not make them the messenger of sensitive information. It is unfair to place them in the position of having to represent the agency, especially when there is an issue of "fault." Show the respect that the community deserves; send an agency representative with authority, such as the District Ranger, whenever possible.

## Phase Three

What if, God forbid, a prescribed natural fire exceeds prescription and personal property is lost? Phase Three demands immediate reaction. Focus on meeting the immediate needs of those affected. Helping people and informing them of available support systems is all important. If trauma counseling is needed, find it. If supplemental hay is essential, acquire it. Leave the summary newsheets and fancy maps until later. Become a provider to the extent of your legal limits. Get to those in need and offer assistance before the media asks for their version of the "story."

Keep in mind that you can never satisfy the needs of everyone. Be sensitive and nurturing to those who have suffered a loss, no matter how small. Keep the confidentiality of those who reveal personal grief.

Timing is everything. Wounds heal slowly. For instance, people on the Missoula (west) side of the Canyon Creek fire were very interested in visiting the burn. Interpretive walks were scheduled with local environmental groups and outfitters. Scheduling these kind of talks on the east side of the fire, where personal property was lost, would have demonstrated a lack of sensitivity to those who suffered personal loss.

## CONCLUSIONS

In conclusion, let me repeat that delivering fire information at the proper time and tailoring it to meet the needs of those affected is critical. Keep in mind that you are dealing with real people who have the same loves, fears, and suspicions that you have. Treat everyone with respect, patience, and above all compassion. The flames eventually go away; the people don't.

# Prescribed Natural Fire Strategies and Tactics

**David E. Poncin**

**Abstract**—Decision making for managers in a fire situation can be very complicated. The information brought to the decision maker must be well thought out and accurate. Before meaningful strategy can be formulated, realistic agreed-upon objectives for the incident are needed. With objectives documented, they act as screens for the strategy and further test the tactics that are developed once the general strategy emerges and is agreed to. The prescription for action on the incident is the tactics. These are determined after the objectives and strategy are in place. Many forces are at work that have the ability to cause change in strategy and tactics: fuels, terrain, weather, availability of resources, political agreement with objectives. Risk is an important factor. Success in the prescribed natural fire program often depends on the manager's capacity to take risks.

As we look at our wildlands after 100 years of fairly successful fire protection, one can only wonder at the ecosystem changes that have resulted from our suppression practices. Vegetation change has created unnatural fuel loading, and this, when coupled with recent drought years, has resulted in some forest stand replacement fires that have been unprecedented in recent history.

These recent fires have greatly enhanced our understanding of the technical aspects of fire. Increasing our knowledge base has made us better, more confident fire managers. It is kind of like looking at a dragon—when you see him at his worst, you understand him best—the flip side is you also respect him more.

Since the mid-1980's, we have seen some spectacular fire behavior. This has resulted in better training and advancement in fire technology that make today's managers better than at any previous time. We need to remember that fire management is as much an art as it is a science. Overconfidence can be deadly, and no fire season or fire is entirely predictable.

My assignment for this paper is to talk about direct and indirect strategies, fire objectives, and light hand on the land tactics, and do this for both wildfire and prescribed fire. Let us be honest, the topic cannot be adequately addressed in this short paper. Our time will be better spent if we address the cycle of a fire that starts as prescribed and goes out of prescription to wildfire status. In doing this I think we can address all the ramifications and potentials as written in our symposium objective.

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## FIRE IN WILDERNESS

The primary objective for prescribed natural fire (PNF) in the wilderness is to "perpetuate natural ecosystems." This objective coincides with the intention of the Wilderness Act, which states: "...wilderness is an area affected primarily by nature, with human activity substantially unnoticeable...."

In the Intermountain West, fire is one of the forces of nature that has a definite role to play in our wilderness. A naturally burning fire and the resulting "natural mosaic of vegetation" will also satisfy several secondary objectives:

- Ultimately PNF's result in fires of a more natural size and intensity as opposed to those of a conflagration nature.
- PNF's maintain biological diversity.
- PNF's enhance wildlife habitat.
- PNF's tend to reduce potential for epidemic levels of insect activity.
- PNF's provide opportunities for visitors and users to observe a natural process occurring in a forest ecosystem.

## RISK ANALYSIS

The prescribed fire manager starts the task before the fire season, preparing people for what the unit will accomplish by working together. It is important that the line officers understand the program, the risks, and the benefits. An opportunity exists to monitor wildfire behavior prior to declaring a fire start in prescribed status. These observations and the use of risk analysis charts will assist the prescribed fire manager with the decision to recommend a fire be considered in prescribed status.

Following is an example of a "Risk Assessment Process" used in an existing prescribed natural fire plan. It involves two sets of factors. The first set has been termed long-term or large-scale risks. They are evaluated when an ignition is first detected and determine whether the fire will be allowed to burn as a prescribed fire or is a wildfire and an appropriate suppression response will be taken. These factors include:

1. Potential fire growth and its threat to life and property and the wilderness boundary.
2. Adequacy of funding for management of the fire.
3. Air quality concerns, particularly to adjacent residential valleys.
4. Fire situation at the national, regional, and local level.
5. The amount of prescribed natural fire that is acceptable and manageable.

6. Long-term drought impacts or effects.
7. Fire season severity, as measured by ERC (Energy Release Component).

This first phase is completed within 2 hours after discovery of the fire. Fires with minimal risk may be approved by the District Ranger in this process. Any fire with a high risk rating for any of the listed factors will be declared a wildfire.

At this point the fire manager immediately moves into a second phase of risk evaluation. This process looks more at short-term or immediate risks—some of these factors include:

1. Potential impacts on wilderness visitors and users (outfitters, etc.).
2. Potential impacts on cooperators, both agencies and individuals.
3. Potential impact on local communities.
4. Existing and forecast weather.
5. Existing and predicted fire behavior.
6. Fuel types and conditions.

These factors require more site-specific information and are examined in detail. This phase includes the preparation of the Prescribed Natural Fire Burn Plan. This phase of the decision process is more detailed, requiring more time. However, this phase is to be completed within 72 hours.

If the fire passes through these two decision-making screens it is declared a "Prescribed Natural Fire." As long as our fire stays within prescription, it will be monitored. This process is reviewed daily by a line officer. The important objective of reintroducing fire into a wilderness has been achieved.

So far what you've read you may already know. I'd like to take a risk and share some philosophy I think works and may help you. Every wilderness has areas that resist or encourage the spread of fire. We find in the Selway-Bitterroot most years the live fuel moisture at about 6,000-foot level is such that it impedes fire movement. (Drought conditions will affect this.) We also have areas in the Selway/Salmon River Breaks where if a fire gets started it consumes large acreages in a hurry. (These areas may be candidates for late-season fires.) And most every wilderness has its area of "goat rocks" where a fire any time during the season struggles for existence.

The point is that by knowing your area, studying the burn patterns, and through the use of logic you can reduce the negative risk when nominating a fire for Prescribed Natural status.

## PNF TO WILDFIRE

In the second phase of planning your Prescribed Natural Fire a maximum allowable Perimeter Fire Map is required. On this map you use your best judgment to determine where the fire will burn and what perimeters you will allow it to burn to. This "map" becomes a constraint on the size this PNF can grow to. When the fire leaves the outlined perimeter (map) it goes out of prescription and as such becomes a wildfire. So, the lines drawn for the map should be defensible lines where, with holding action, the fire can be stopped.

Other factors that may remove the fire from prescription status are:

- When the fire leaves the wilderness or Fire Management Plan area.
- When life or property are threatened.
- When funds are no longer available to manage the fire in prescribed status.

When a Prescribed Natural Fire leaves prescription and becomes a wildfire, the rules change. But your options need not be reduced to one, that being control. Appropriate suppression tactics are an art. Selecting and implementing the appropriate suppression tactics is the art of managing a wildfire without causing resource damage or being detrimental to the identified management objectives. It means the actions taken are effective and necessary to counteract a fire's existing or potential behavior. Basically, implementation of appropriate suppression response is doing the job of controlling or extinguishing a wildfire while maintaining a high standard of "caring for the land."

Selection and implementation of appropriate suppression tactics involves:

- Skillful application of suppression techniques.
- Utilizing principles of fire behavior knowledge.
- Being constantly aware of the surroundings.
- Observing actual fire behavior as well as assessing potential and expected fire behavior.
- Performing these tactics in a safe manner.

The change from fire control to fire management initiates a new perspective outlook regarding suppression of a wildfire. The objective of putting a fire dead out has been replaced by the need to make unique decisions with each fire start, to consider the land and resource objectives, and to decide the appropriate suppression response and tactics that result in minimum cost and resource damage.

There are situations where the decision involves suppressing fire "with time" in contrast to against time. Implementation of the appropriate suppression response may at times involve total suppression of an ignition, or it may be periodic suppression actions along portions of the fire's perimeter for several weeks. This challenges the fire manager and fire fighter to select suppression tactics commensurate with the fire's potential or existing behavior, yet leaves minimal environmental impact.

And sometimes we don't do this well....

## DOING BETTER

As we look at the reintroduction of fire into the wilderness in a prescribed natural program, our accomplishment is not good. As agencies, our managers, born of the suppression era, do not accept the 30,000-foot smoke column on a red flag day as a natural event. It is difficult when the suppression adrenaline is flowing to resist the temptation to "just put the damn thing out."

But resist we must if fire is to play a natural role in our classified wilderness. And we need to look at our accomplishment; it is not acceptable if we are to bring natural fire back into reality. The Selway-Bitterroot has one of the most successful natural fire programs in the Forest

Service. Our annual average is 31 PNF's burning 4,300 acres per year. When we look at the size of the Selway-Bitterroot Wilderness and the role fire has played in the ecosystem, this program is not returning fire to its natural role. The record for the Frank Church-River of No Return Wilderness is 14 PNF fires burning 4,900 acres per year.

This past week, I attended five public meetings Forest personnel were holding to bring back the natural fire program in the Gospel Hump Wilderness. The meetings were not well attended, but those people that did turn out after they heard of the program and got answers to their questions are in support of the natural fire program. Some of these folks have private inholdings in the wilderness that have been and will be threatened. Public support of the PNF program in general is with us.

As with many programs, our problems stem from our inability to convince our own people of the program merits—our failure as fire managers to start early in a positive fashion and sell the program with enthusiasm.

Anyone can apply tactics to a fire program, either prescribed or wildfire. Most people can come up with suppression strategies if they are given the objectives. It is tough to come up with long-range enduring strategy for a prescribed natural fire. The process nuts and bolts are there, if we will but follow the plan. Overcoming the internal resistance in our line officers and colleagues is the tough part. It can be done if we will but build the program on a sound, well-thought-out basis—a dialogue early on that speaks to program advantages and lays out the risk—communication without surprises and a program built to gain support at all levels.

Remember success is a journey, not a destination. By applying our skills in communication and our knowledge of fire, we can successfully make our prescribed natural fire programs a reality.

# Implementing Programs and Future Opportunities: East and West

Gardner Ferry

The objective of this series of presentations is to look forward, and listen as the speakers share with us their perspectives on "Visions of the Future" regarding fire in wilderness and park management. As with the previous speakers we once more bring to you a tremendous group having a wide spectrum of personal and professional experience and backgrounds. Because of the subject matter for this panel, the speakers were informed the sky is the limit on their opinions and there are no rights or wrongs. Each was asked to use their past and current situations to call it as they see it.

You must have some empathy for these last four speakers. They sat patiently through the week and heard one excellent presentation after another where bits and pieces of their speech were given and new ideas were presented. Each night while we relaxed, they went back to their motel rooms and spent the evening busily revising their speeches. It should be interesting to hear what they say.

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Before I introduce the speakers I want to pass on some information that you might find interesting and refreshing. You might infer from some of the comments and might leave with an incorrect impression that many fire management personnel, especially those with significant suppression workloads, are not aware of or sensitive to suppression impacts and the unique considerations that go with natural area management. I believe this type of impression is entirely incorrect if you look at the general population of fire managers. As an example of just how much consideration is being made, you should be aware that at the national incident commanders meeting a few weeks ago this was a major topic. Several hours were spent addressing levels of acceptable suppression impacts, suppression rehabilitation activities, and ways to work with managers to identify these concerns up front before the suppression teams take over the fire. The suppression personnel, whether they are local or national teams, work for the forest, park, district or refuge manager. It is the manager's responsibility to clearly identify the objectives, constraints, and restrictions to the incident commander. The discussions that are occurring in this symposium and at suppression sessions are healthy, and as long as they continue, change in the right direction will also continue.

# Smokey Science Meets Ecosystem Management: A Vision of the Future

T. Destry Jarvis

> The only real capital of a nation are its natural resources and its human beings. So long as we take care of and make the most of both of them, we shall survive as a strong nation, a successful nation and a progressive nation—whether or not the bookkeepers say other kinds of budgets are from time to time out of balance.
> Franklin D. Roosevelt

Good afternoon. I want to especially thank the conference organizers for inviting me, on behalf of the Student Conservation Association, to address you in this conference.

President Roosevelt's comment about people and natural resources is perfect for this conference, in my view, and for the times in which we live. Both people and resources are finite and fragile, but with good management, can be sustainable and sustaining of our Nation.

Partnerships are a big theme, both among your agencies, and all across the country. I see them and hear about more virtually every day among non-profits; between non-profits and related agencies; and increasingly, among agencies, non-profits, and for-profits. The Student Conservation Association has had strong, effective partnerships with your agencies for decades, and the partnerships are growing both in size and sophistication.

Another old adage is appropriate to your situation today - "Limitation is the mother of good management." Despite the possibility of a supplemental appropriation this year by the President's "economic stimulus," we are in a lean time for public land agency budgets, and that means that partnerships will be an increasingly effective, and necessary means of achieving your mission. Organizations like the Student Conservation Association, which have no political agenda, but which exist to provide volunteer, or minimal wage assistance in conservation and land management, and in training your field crews, are available to you.

## CONSERVATION CORPS

There are now some 80 state or local conservation corps across the country which are set up to do work out-of-doors, and to provide service. They are underutilized at present by your agencies.

President Clinton's call to "national service" and his establishment of a White House Office of National Service indicate that there is support at the top for you to expand your work force in the field through use of youth and young adults in conservation service.

The Student Conservation Association, virtually alone among national non-profits, offers you crews of youth, supervised by adult personnel for physical labor conservation service projects in the summer time (the High School Program); young adult conservation service volunteers to work in individual placements, like interns, in semi-professional career-developing job experiences (the Resource Assistant Program); and field work skill training for your staff and the leaders of other service organizations (Wilderness Work-skills Training Program).

In addressing yet another high priority need, the association also offers the Conservation Career Development Program, which targets highly capable young men and women of color for a year-round, multi-year program leading them, through a series of field training experiences, career tracking, counseling, and mentoring, into an entry-level conservation career.

Finally, the Student Conservation Association promotes careers in your agencies through "Earth Work" magazine, our new monthly conservation career publication. Not only will "Earth Work" list your vacancy announcements for free (we attract a far more diverse pool of potential applicants than you do), but we profile your agency, and individual people who work in your agency, as a way to attract attention to the conservation field, to explain to career aspirants how to find a conservation job, and to let them know what it will be like to work for your agency.

Thus, the Student Conservation Association exists, in large part, to serve your mission, and to assist you, through an effective partnership, to carry out needed conservation management tasks on the public lands.

Moving beyond the specific value of the Student Conservation Association and other conservation service organizations, I want to come back to the theme of limitations, because they are real, and because you cope with them every day.

## PARTNERSHIPS

At the risk of being overly simplistic, I see a continuum, or an interconnected sequence, which goes something like this:

- Limitations create an atmosphere receptive to partnerships
- Partnerships lead to cooperative management
- Cooperative management leads to ecosystem management

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- Ecosystem management leads to biodiversity
- Biodiversity leads to a healthy, balanced environment, both locally and globally, and is a major goal of modern society.

How is this relevant to you and this conference, you ask? In the multiple-use management regime which applies to a greater or lesser extent to each of your agencies (and believe me even national parks and wildlife refuges are multiple use, but not every use), the ecological principles embodied in terms like "the web of life," "biodiversity," and "ecosystem management," will take a predominant role in management decision making, including the question of fire management, not just fire suppression, and fire ecology.

On the practical level, these principles are also related to the announced intent to establish a new National Biological Survey in the Department of Interior (Can Forest Experiment Stations be far behind?). Interior Secretary Babbitt, correctly I believe, has identified a significant gap in both knowledge and the means to get it, regarding the biological resources of the Nation, and has also ascertained that the function is logically universal, and not the purview of a single agency.

His practical example of not waiting for a species to become endangered to secure protection for its habitat, both an inherent virtue, and a practical means of avoiding the onerous burden of the rules of the Endangered Species Act, is right-on. Proactive anticipation of potential management problems is the best means to avoid them altogether.

## SCIENTIFICALLY BASED MANAGEMENT

The federal land managing agencies have made substantial progress in the scientifically based management of public lands, especially in the past 25 years. Within all areas of public land management, perhaps the most impressive accumulation of new knowledge applied to resource management decisions is in the area of fire ecology and fire management.

A prevalent view in the 1960's and 1970's among some professional resource managers was that "trees are like cabbages, meant to be harvested" as S. I. Hayakawa once said about the redwoods. Sure, some trees in some places are meant to be harvested, but not all trees in all places. If you hold the cabbage view of trees, then total fire suppression is the obvious management decision.

For the future, a greater emphasis on managing to promote biodiversity on the public lands will be a dominant mandate. Better cooperative management among adjacent federal land managers will be essential. In fact, even in a situation where no new knowledge was made available, huge strides in improved management of the public lands could be made simply by achieving better cooperation in planning and decision making among federal agencies.

The prior and current examples which your agencies have demonstrated in coordinating on fire suppression, fire management and fire ecology, set an appropriate course for future cooperation and coordination on other policies and procedures related to the biological resources of the public lands. Secretary Babbitt should be impressed with your record in fire management, and you can take heart that this success can breed other successes in cooperative land management in the future. I think that the National Biological Survey should be welcomed with open arms, and not feared as intruding on your management prerogatives.

## POLITICS AND PUBLIC EDUCATION

In addition to partnerships and science, another important factor in the future of your programs is politics. Closely related is public education. The latter informs and can shape the former, and you must be proactive in getting your message to the public. Explaining the "let burn" policy while the Yellowstone ecosystem is on fire is, obviously, too late.

Politics, and the constant influence of politicians, in the Congress and in the Administration, is a fact of life in the American political system. It should be welcomed, even relished, but you have to know how to deal with it, and you absolutely need to be proactive, dealing directly with the elected and appointed political leaders, and most importantly you must have an aggressive public outreach and education program.

Of course politics will always be a major factor in the American governmental system, as it should be, and land managers, once they become cooperators, must also become more adept in the arena of public policy formulation. Don't leave it to the politicians.

Enactment of the National Environmental Education Act, and its applicability to every federal agency gives you an important tool with which to develop this outreach effort. The National Park Service has its new "Parks as Classrooms" program, and the USDA Forest Service has its "Urban Treehouse" program. Use these vehicles to educate the public.

As a Scoutmaster in the Boys Scouts of America, and even earlier as a Cubmaster of younger boys, I can tell you that kids are fascinated by fire. They love to start fires, and to sit around the campfire at night. It's a primeval instinct. Use this fact to implement your education program.

## CONCLUSIONS

Thus, innovative partnerships, cooperative land management among agencies, and application of ecological principles to management, all steeped in the churning cauldron of politics, and leavened with public education, are the future vision.

Thank you for this opportunity to further acquaint you with the Student Conservation Association, and to offer some insight, and some hope for the future.

# Wilderness and Park Fire Policies and Programs: Vision of the Future

**Jack Neckels**

Not many years ago, Euell Gibbons sold breakfast cereal by telling the television audience that it "tastes like a wild hickory nut." He tried to convince the viewers that his cereal was more natural, and therefore healthier and better than other breakfast cereals. The thinking consumer may have been a bit suspicious when the buzz words "natural" and "wild" were used to elicit warm fuzzy feelings about a processed grain product. The use of the word "natural" may have been less than circumspect when Webster's definition of "produced or occurring in nature; real; not artificial or manufactured" is the measure. Selling things with the "natural" label can be deceiving.

Wilderness managers are charged with preserving for the public a commodity that the words "wild" and "natural" are associated with. The Wilderness Act says that designated wilderness is to be "managed so as to preserve its natural conditions." That is one of the goals of wilderness management. However, our track record, at least in the National Park Service, hasn't always been the best at knowing what is "natural," let alone "wild." A lot of effort went into killing "bad" animals in the parks so there would be lots of "good" animals for the tourists to see. Natural resource managers in the Forest Service operated under their own assumptions. In 1921, Aldo Leopold wrote about paying "special attention" to predators so there would be more deer to hunt. It's hard to say that Leopold and his contemporaries in Yellowstone were consciously trying to adversely change the natural order. People, then and now, joined land management agencies because they valued the natural world. In looking back, it's obvious that our understanding of what is "natural" has changed. Looking toward the future can be more obscure.

In looking at managing wilderness so natural conditions are preserved, we now see that anything we do, and that includes doing nothing, can affect wildland resources. Part of the problem comes with the conundrum of "wilderness management." When mankind tries to manage wilderness for any reason, to preserve trees from fire or pests, to manage wildlife to favor one species over another, to maintain a vegetated scene like the pioneers described it, it may seem to some to not be "natural" anymore. Stories in the press tell how man's fire suppression has created unnatural conditions in the wilds. In some cases, that's probably true; and in some cases, false. A lot depends on the natural fire regime.

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## WHAT IS THE NATURAL ROLE OF FIRE?

In 1897, T.S. Brandegee of the U.S. Geological Survey visited the Teton Forest Reserve. His report stated: "It is only occasionally that tracts of timber of merchantable size are found, and areas containing notable quantities of merchantable timber are few and limited. This condition appears to be due simply and solely to fires that have swept over the country so completely and persistently that scarcely any part has been exempt from them, while nearly all portions have been burned again and again within a generation." Research has confirmed that fire played a major role in shaping the soil, vegetation and wildlife patterns in the area. Fires were frequent and widespread, and occasionally large.

Fire has been a part of the natural order in the Yellowstone area for thousands of years. In 1988, it was assumed that the large fires would kill large numbers of the charismatic megafauna (elk and buffalo, for instance) that tourists want to see. There was some mortality, but not much considering the scope of the fires. In fact, elk were seen walking in the smoldering burned areas near active flame. It can be assumed that the elk instinctively knew that fire was part of their natural world.

In trying to decide what is "natural," it is hard to separate human assumptions and expectations from what is permissible within the scope of natural variation. Reactions to the 1988 fires in the Yellowstone area are enlightening. President George Bush came out for a helicopter tour of the "scenic destruction." Even after the Park Service's best efforts at education, Secretary of the Interior Lujan was distressed at the amount of devastation. Tourists still bitterly complain about the National Park Service allowing Yellowstone to be "ruined."

To many people, "natural" is defined by green trees, (possibly) grass, and surface water. A study of visitor attitudes about resource impacts in a state park south of Indianapolis, Indiana, expected to find that people's recreational experiences were degraded by the bare ground and the maze of exposed tree roots in the campground. Instead, the visitors were found to be having a great experience in nature. There were leaves overhead, and they were away from the hurried pace of urban life. As the 1988 fires demonstrated, the public has strong feelings about how their wildlands are managed. Most seem to have some idea of what is "natural" to them, and they expect to see their dream when they visit a park or wilderness.

As the 1988 fires demonstrated, fire, and recent fire effects, don't fit into much of the public's idea of what they want to see when they visit a natural area. When the wilderness visitor plans a trip, there are assumptions and expectations in mind that will affect the satisfaction derived

from the trip. If the expectations aren't met because a recent fire, or the smoke from a prescribed natural fire, has altered the scene away from their view of natural, they often complain. Since most land managers are public servants, those complaints can affect how things are done in the future. Education will be a big part of the future.

Factors that should be considered in deciding what is "natural" include the native plant and animal life, surface water and land forms of an area. What is harder to see, but is just as important, are the natural processes that continually shape and change the natural world. It takes a trained eye and educated mind to realize that the natural scene that is encountered on a visit to a park or wilderness area is in a state of flux. The changes that go on continually range from obvious seasonal changes related to life cycles of vegetation and animals, to:

- Less obvious changes of dead trees on the edge of meadows that died during a drought
- Successional changes in the plant communities
- Dramatic changes due to erosion such as occurred on February 3, 1993, when thousands of tons of rock on the face of Millard Ridge at Badlands National Park disintegrated
- Wave after wave of boxcar-sized blocks tumbled for over an hour
- When new land is created or subsides due to volcanic activity in Hawaii
- Large stand-replacing fires in a drought year
- Climatic change that causes continental ice sheets to wax and wane.

Another factor whose role in the natural world isn't agreed upon is the human population. Small groups of people living in the Amazon basin using Stone Age tools are assumed to be part of the natural world when they are first contacted by people from the modern technological world. But the question can be asked, are both of these groups part of the natural world? Certainly modern man has changed the face of the Earth to a dramatic degree. But early man also was an agent of change in his world. Fire was a tool used to manage vegetation. Fire is still used by shepherds in the Andes to improve pastures. This traditional burning has gone on for hundreds of years. Where on the continuum of changing the face of the Earth does the human population go from being a part of nature (a wildlife population with tools and intellect), to an unnatural force (with tools and intellect)?

The definition of "natural" will underlie the direction of fire management in the future. Good science will be needed to continue to gain a better understanding of ecosystem dynamics related to nutrient cycling, vegetative cycles and community structure. With better understanding of the natural processes, education of the public about the less obvious factors will hopefully gain acceptance of the fact that fire and fire effects should be included in the realm of what is natural. Instead of people seeing fire and fire effects as "good" or "bad," they will hopefully accept them as "okay."

When a large fire results in erosion that puts soil into a stream, the effect isn't the ruination of the stream. Certainly there are changes. And the changes may not be good for the trout fishing for a few years. But siltation from fires has gone on for centuries, and there are still trout and aquatic insects in the streams. Many factors that the public see as being unacceptable within their view of what is natural are related to disturbance. The only constant is change. Increasing the knowledge of the processes involved and educating the public, especially about realistic time frames, will be key to fire management in the future.

## THE NATIONAL PARK BALANCING ACT

The national parks must balance the twin mandates of tourist entertainment and resource preservation. This challenge stems from the 1916 Organic Act which directed the National Park Service to "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." In the early years, managers sought to encourage visitation so the public would support the parks. A result of this was to shoot predators so there would be more "good" wildlife to see. The National Park Service accepted the thinking of the time that all fires must be suppressed. Even though the parks were to be preserved, there was something bad about letting good trees burn for no good reason. The realization that preservation included natural processes came later.

Over the years, the National Park Service has moved from actively seeking to attract and satisfy visitors to managing visitor numbers and effects. In the 1930's, two men wrote the superintendent of Grand Teton National Park asking for help in doing a first ascent of one of the mountains. A ranger was assigned to lead them to an unclimbed summit. Today the climbing rangers are too busy rescuing visitors and enforcing regulations to be guides. As use increased, so did regulations and management actions. In 1970, the first wilderness areas were designated in the National Park System. Park management valued the new wilderness areas solely for the recreational use they received. Starting in 1981, non-recreational values started to be recognized. The Park Service still views the trend of acknowledging the non-recreational value of wilderness in anthropocentric terms (Coffey, 1990). The pendulum is slowly swinging toward a more biocentric view, but the visitor use mandate will allow it only to go so far.

## THE FUTURE OF FIRE IN THE NATIONAL PARK SYSTEM

The role of fire in National Park Service wilderness management will increase as more parks in fire-dependent ecosystems gain a clear understanding of their natural fire regimes. Research will play a large part in this process. Education will also have to be a key component. As the borders of parks and wilderness areas are crowded by development, the natural role of fire is becoming more restricted. In some areas, it is not feasible to allow natural fire to decide the "when" and "how big and hot" of burning. Pinnacles National Monument is a good example. The size of the area and the fuels involved, combined with the developed areas around the monument, make large,

hot fires unacceptable. Managed fires around the perimeter are designed to replace fires that might have started outside of the wilderness but would have come across the boundary if they weren't suppressed. This managed buffer will hopefully allow natural fire starts in the core of the wilderness to burn more naturally without threatening development outside of this small park area (DeBenedetti 1989).

The challenge in areas like Pinnacles is to allow fire to play as natural a role as possible while addressing the neighbors' concerns. Is it possible to meet the "managed so as to preserve its natural conditions" direction of the Wilderness Act? As the population increases, will the Pinnacles situation be the model for most wilderness areas in the lower forty-eight states? Already there is great difficulty in allowing large stand-replacing fires such as occurred in Yellowstone in 1988. Research will have to tell us if those fires are necessary to meet the Wilderness Act's intent. Time will have to tell if we can control them when things get extremely dry and lightning flashes.

The future holds many challenges for wilderness fire managers. The idealistic desire for natural fire directed by the Wilderness Act will have to be balanced with the pragmatic realities of fire in a land crowded with people, and with people's values. The integrated fire management approach being practiced in Sequoia and Kings Canyon National Parks that combines fire suppression, prescribed fire and prescribed burning (Warren 1989) will likely be widespread in the future. Critics may charge that using prescribed fire and prescribed burning in wilderness doesn't fit the "natural fire" test of the Wilderness Act. Looking back to the question of where did man fall off the "natural" wagon, I suggest that we are still on it. We certainly aren't all-knowing, and admittedly we are fouling our nest in many ways. But just as the shepherds used fire as a tool centuries ago, we are still "a wildlife population with tools and intellect." Prescribed fire uses the tool of fire in combination with intellect. That is not unnatural.

Wilderness managers obviously have a great responsibility when using and managing fire. Knowing what's right and wrong in making decisions that obviously have far-reaching effects should cause the decisionmaker to pause. Guidance can be gained from Leopold's land ethic. He said that, "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (Leopold 1966). The definition of stability has to include the natural variations, including the effects of natural "disasters." Too many people feel that "preservation" means maintaining the status quo. Wilderness should preserve the opportunity for process rather than form (Coufal 1990).

Wilderness management is important to a large segment of the public. The 1988 fires showed that clearly. It is also clear that fire is an integral part of the wilderness. Educating the public, based on solid research, will be an important component of wilderness fire management in the future. As human developments surrounding parks and wilderness areas increase, and as the effects of smoke and fire crossing boundary lines occur, managers will have abundant opportunities to use their public relations skills as they pursue the goal of managing fire "to preserve natural conditions."

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# A Vision for the Future of Fire in Wilderness

Veto J. "Sonny" LaSalle

We have made significant progress in managing fires in parks and wilderness since the old "10 a.m. " policy days, when every effort was made to control fires discovered one day by 10 the following morning. However, the combination of weather patterns and vegetative conditions is creating the opportunity for naturally occurring fires that European man has not seen. We need a "quantum leap" in public understanding and acceptance of naturally occurring fires in wilderness and parks if we are to truly manage fire under current conditions. Developing historic weather patterns and fire histories are a must for us to understand and explain the natural role of fire in our ecosystems.

This has been an exciting week for me to see many old friends, make some new ones and associate with people who share my philosophy about the natural role of fire in our ecosystems.

Preaching to the choir is always more pleasant than discussing hotly contested issues with people who have strongly polarized views. We will have to do so, but that topic comes later in my presentation.

William R. (Bill) Kreutzer was the first Forest Ranger for the Forest Service. He was hired in Denver in 1898 and was told to head for the Plum Creek Timber Reserve as fast as the Almighty would let him, and get up there and put those fires out. We have had a long and celebrated history of fire prevention and fire suppression.

We have come a long way since 1898, but the journey is far from over.

## PAYETTE STORY

I was supervisor of the Payette National Forest from 1986 to 1992 and was fortunate to be there, with an outstanding staff, during some record-breaking fire years. They were record breaking, that is, for the period we have been keeping records.

Lightning-caused fires covered about 250,000 acres during my 6-year watch and most of that was considered out of prescription due to our perception of a severe drought. About 175,000 acres burned in a confine or contain suppression response.

We set a high priority on allowing fire to play a more natural role for prescribed fires and doing high quality escaped fire situation analyses to determine the appropriate suppression response. We also recognized the potential barriers to our efforts and developed a plan to convert those barriers, people in this instance, to our way of thinking. Dave Olson, our Public Affairs Officer, was a very busy young man for the first few years working with the media in McCall and Boise. We flew them over and into the wilderness during and after fires. It wasn't long before media interest in our fires dwindled to minor coverage.

We worked with the Idaho Outfitters and Guides Association, local outfitters, backcountry pilots, wilderness landowners, and other wilderness users on a regular basis before we had active fires. We kept the telephones busy during the fire season to ensure we kept our "no surprises" pledge .

I personally spent time with the Governor, Congressman Larry Craig (now Senator), Senator James McClure, Congressman Larry LaRocco and their Boise staffs to ensure they understood the historical role of fire in development of the condition of our present-day ecosystems. We didn't always find agreement, as Smokey has done an outstanding job, but we did achieve understanding.

Suppression of fire in wilderness is expensive, and we need to let the public and elected officials know the total cost of fire suppression efforts. From 1985 to 1992 direct fire management in the Frank Church River of No Return Wilderness cost:

- Prescribed natural fire ...................... $0.31 per acre
- Wildfire under a control response ...... $1,085 per acre
- Wildfire under a confine or contain ... $132 per acre

It is interesting to note that most of the $132 per acre to confine or contain wildfires in wilderness was spent in protecting structures—both Forest Service and private structures, but mostly private.

I actually had more problems internally than I found in the public arena. This may be hard for you to believe, but in many cases it was a constant battle to have prescribed natural fires. I had pressure from an adjoining Region, adjoining Forest Supervisors, and my own Regional Office. It was okay to call the fires wildfires with an appropriate suppression response equating to confinement, but it was not okay to have them in prescription, especially in June or July. The pressure really got hot after the Yellowstone fire and its associated "political heat."

## ELECTED OFFICIALS

Our elected officials, from city and county governments to congressional delegations, have personal views about fire in wilderness and parks. They also have to represent the views of their constituents. When their personal feelings match those of their vocal voters—watch out. Forest

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Service leaders are especially responsive to members of Congressional delegations and that's not going to change.

The Yellowstone fires taught us many lessons and the role of elected officials is one we shouldn't easily forget. Many Forest Service folks, including the Chief, do not want to go through that again. I am sure Park Service leaders feel exactly the same way.

What have we learned from the Yellowstone fires—both politically and ecologically? How can we use that information to help us in the future? Another such fire season will happen again somewhere, especially if we continue as we are now.

## FOREST SERVICE LEADERSHIP

As I said earlier, the leadership of the Forest Service, and I believe the leadership of the Bureau of Land Management and Park Service, have a history of being responsive to elected officials; we shouldn't expect that to change. It's good business to listen to and respond to the people who control the purse strings, and who pass laws that govern our reason for being.

We will be responsive by spending money on large wilderness fires when we know that we have little hope of effective suppression. We will have potentially long-term effects on wilderness resources to give the appearance that we are trying valiantly to put the fires out.

There are many people who are interested in healthy, natural, wilderness ecosystems. Michael Frome wrote a letter to Chief F. Dale Robertson on July 10, 1992, commenting on Chief Robertson's June 23 congressional testimony on the "National Forest Wilderness Management Act." Mr. Frome stated:

> I was especially pleased to note your intent to focus more effort on addressing the ecological health of wilderness areas, and determining whether the ecological health is improving or deteriorating.

The willingness to take risks with fire varies greatly within leadership in the Park Service, Forest Service and Bureau of Land Management. The differences are personal and are not determined by the particular agency for which we work. We will always have some risk in decision making, but we can reduce the need for risk in decisions associated with fire.

## SCIENTIFIC KNOWLEDGE

We know more collectively than any of us realizes, and we learn more every year. We were making Regionwide decisions in Region Four based on the "unusual" drought and the previously unseen fire behavior. I heard about a paper dealing with tree-ring chronologies that displayed weather patterns over a long period of time. I was still on the Payette when I heard of the paper and I asked some folks to help me find it as I was questioning the fire decisions we were making. It took months to locate the paper that had been published in July 1980. The paper, "Annual Precipitation for California since 1600 Reconstructed from Western North American Tree Rings," by Harold C. Fritts and Geoffrey A. Gordon, addressed the very problems we were having. No one in Idaho I talked to had ever heard of it. Fritts and Gordon were with the Laboratory of Tree Ring Research at the University of Arizona in Tucson when they published the paper.

There are many important conclusions and other data in this report that I encourage you to read. One conclusion that I felt had a lot of impact from a decisionmaking standpoint was that we should not anticipate climatic conditions evaluated exclusively from existing weather records.

The paper documented many dry periods from 1600 to 1980 that were equal to or greater in magnitude and duration than the recent seven years. This type of information is a must for modern-day decision making and the intensive education effort we must undertake.

## THE FUTURE—WHAT TO DO?

Dave Jolly, Regional Forester, USDA Forest Service, Northern Region, made the following excellent points in his opening remarks:

> When it comes to managing fire in wilderness and parks you can pay now by allowing fire to play a natural role or you can pay a lot later by trying to suppress fire.
>
> What are the true impacts of fire suppression? We know about the long-term impacts of active fire suppression on wilderness resources, but what about the long-term ecological impacts of not allowing fire to play a natural role? Where are our NEPA (National Environmental Policy Act) documents for decisions on full suppression activities? It is possible that full suppression of fire has more long-term impacts on our ecosystems than all our other activities combined.
>
> We need a deep understanding in our bones for wilderness and we need to get our hands off wilderness.

Mike Manfredo of Colorado State University in Fort Collins said the need for education about fire is high and the cost should not be underestimated.

Conrad Smith of the School of Journalism at Ohio State University in Columbus demonstrated how the media creates an erroneous impression about fire by using words like destroy, devastate, and victim.

If we take a hard look at how the "system" works, the choices are pretty clear. We can continue gathering data, developing knowledge, and preaching to the choir with limited outreach and enjoy some progress.

Or we can make a major commitment to gather all our knowledge, develop significant partnerships and launch an education effort that some of us have only dreamed about. Get away from the choir and into the fire.

Our three agencies have the information and resources to make this happen. What we lack is commitment.

Ecosystem management is a focus point in our agencies, and it is an excellent concept to use in education about the role of fire in our environment.

We should model our efforts on something that has worked—Smokey Bear. We should make this a long-term approach and focus on all age groups.

If we can change people's perceptions about fire we will significantly reduce the political pressure placed on our leaders to spend money where it isn't needed, leaving impacts in wilderness that clearly display the effects of man's activities.

I consistently include a discussion of the fire history of the White River National Forest when talking to county commissioners, city council members, environmental groups and others. The value of the scenic beauty surrounding Aspen, Vail, Dillon and other mountain communities is measured in the hundreds of millions of dollars each year. Most of the diversity of the landscape has an origin in naturally occurring fires, and most people are unaware of this. Many of them believe it will remain as it is if we just leave it alone.

We have partnerships to develop "educational boxes" for Project Learning Tree, Project Wild, and endangered species such as the wolf. There are many partners who would participate with us to develop "boxes" and videos on natural fire to use for all grade levels in classrooms across the country. Teachers are always looking for natural resource education material. The 50th anniversary of "Smokey the Bear" is coming up. Let's feature how much Smokey has learned about fire in the last 50 years—fire has beneficial effects in some special places.

My vision for the future of fire in wilderness and parks is bright, if we commit the necessary resources to share our knowledge. We three agencies should be together with academia, interest groups, and corporations, sharing in an effort to educate the public and their elected officials concerning the natural role of fire in our ecosystems. My basic question is: Who will take the lead?

# Posters

# Fire Growth Simulation for Prescribed Natural Fire

**Patricia L. Andrews**
**Collin D. Bevins**

Prescribed natural fire presents fire behavior prediction questions that go beyond those that traditionally have been asked about wildfire and management-ignited prescribed fire. Time and location of ignition are not a choice as they are with management-ignited prescribed fire. And fire growth projections must go well beyond the next firefighter work shift as is usually done for wildfire. In addition, ecosystem management questions are being asked about the role of fire in general, and prescribed natural fire in particular.

A fire growth simulation model under development by the Fire Behavior Research Work Unit and Systems for Environmental Management will help prescribed natural fire decisionmaking at several levels:

- Examination of fire policy with respect to ecosystem management considerations and wilderness management objectives.
- Development of fire management plans and prescriptions for prescribed natural fire.
- Designation of an ignition as a wildfire or a prescribed natural fire (the go/no-go decision).
- Revalidation of the fire as a prescribed natural fire throughout its lifetime.

We describe features of the simulation and how we envision it being used for prescribed natural fire in each of the four levels of decisionmaking.

## APPROACH TO THE SIMULATION

The authors developed a GIS-based fire growth simulation until its potential was evident. Rather than continue toward the short-term payoff of a demonstration product, we chose a more difficult path with a greater long-term payoff. We have been developing a software framework for fire and ecosystem modeling—designated "Loki" (Bevins and Andrews 1994).

In addition to prescribed natural fire applications, the simulation will be used in other aspects of wildland fire management including training, determining wildfire suppression tactics, and economic analysis of fuel treatment options (Andrews 1989). For a simulation to be applied to the range of needs, it must be flexible. The Loki framework provides this flexibility.

Loki is based on the concept that system developers should be able to select models from a "tool box" and use them to build a system for a specific application. Models in the tool box can be independent entities developed by experts in their own specialty. Models for fire spread, smoke production, tree mortality, and stand succession, for instance, can be developed independently and incorporated into a single simulation system.

Loki will make it possible to select appropriate models for a specific application. For example, a current vegetation or fuel map and observed and forecasted weather would be used to simulate the next day's growth of an ongoing fire. In the planning stages, however, a vegetation succession model, fuel accumulation and decay models, and climatology would be part of the simulation.

## ECOSYSTEM MANAGEMENT PLANS AND PRESCRIBED NATURAL FIRE PRESCRIPTIONS

Wildland fire is an important factor in ecosystem dynamics (Williams and Rothermel 1992). The simulation can be used to examine the role of fire over hundreds of years by examining ecosystem and landscape change under various scenarios, ranging from fire exclusion, to allowing all fires to burn, to the use of prescribed fire in selected locations. The results can be compared to the desired future conditions. In addition, design of the simulation will allow disturbances such as insect and disease or logging to be included. Results can be visually displayed, illustrating risks and ecological tradeoffs to policy makers and to the public.

## FIRE MANAGEMENT PLANS AND PRESCRIBED NATURAL FIRE PRESCRIPTIONS

Once it is determined that prescribed natural fire has a role, fire management plans and prescriptions are written. The simulation is one of the tools that can be used in the process. The simulation can examine various "what-if" scenarios for fire location, time of year, fuel condition, and weather. The location and conditions under which prescribed natural fire is an acceptable option can be determined. The simulation may also be used to examine the effectiveness of fuel treatment by management-ignited prescribed fire or other methods for protecting structures, boundaries, or inholdings.

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Weather conditions can be based to some extent on climatology, certainly for "most probable" scenarios. But one of the lessons of the 1988 fire season was that the "worst case" conditions may not be in the weather records (Rothermel 1991). This is the time to define the most probable and severe weather, not during the time crunch of a go/no-go decision.

## THE GO/NO-GO DECISION

Many factors must be considered in making the decision to declare a new ignition a wildfire or a prescribed natural fire; potential fire growth is one of them. Day-to-day growth is not as important as the final perimeter location with respect to the maximum allowable perimeter established for the fire. The question is whether the fire will cross a given line before it goes out.

The short-term forecast done by a Fire Behavior Analyst for the next work shift on a wildfire (Rothermel 1983) is not sufficient nor appropriate for a prescribed natural fire. The forecast must go well beyond the time for which reliable weather forecasts are available. The simulation will aid thinking in terms of probability and risk. It is not possible to predict exactly what the fire will do, but the simulation will permit "gaming" of possible outcomes.

Once the ignition has occurred, we know the location, time of year, state of fuels, and the weather to date. The simulation can incorporate current conditions and the most probable and severe weather scenarios defined earlier, as well as long-term trend forecasts (McCutchan and others 1991).

Risks associated with various scenarios can be displayed to decisionmakers. And once a decision has been made, display of the simulation's results can be help to explain the decision process and fire potential to the public.

## REVALIDATION AS A PRESCRIBED NATURAL FIRE

As the fire progresses, more information becomes available, including observations of actual fire behavior. The simulation must be able to use information from the fire itself, in addition to mathematical fire spread models. In addition to gaming long-term behavior, daily projections based on weather forecasts can be made, like those made by a Fire Behavior Analyst on a wildfire.

## FEATURES OF THE SIMULATION

In keeping with our decision to work for the long-term payoff, we are designing the simulation for "fast" Unix-based workstations with "lots" of memory and storage. Computer technology is advancing so rapidly we feel that this is the proper approach.

We recognize there will not be an accepted computer hardware and software standard among land management agencies for some time, if ever. Therefore, coding of the Loki software framework is being done in the C programming language; it does not require a specific brand of GIS software. Conversion routines can be developed for various file structures.

The simulation will have a sound, well-documented scientific base. Visually appealing products make it easy to overlook the internal workings (guts) of a system. We are concentrating on both. Loki will be a research tool that will allow mathematical models under development to be easily tested and compared.

We foresee that the fire growth simulation will be used for many fire management activities, including various levels of prescribed natural fire decisionmaking. The Loki software framework for fire and ecosystem simulation will provide the needed flexibility.

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# Fire Danger Rating and the Go/No-Go Decision for Prescribed Natural Fire

**Patricia L. Andrews**
**Larry S. Bradshaw**

The decision to declare a new ignition either a wildfire or a prescribed fire is a difficult one. The designation must be made in a timely manner, and the decision embodies a high degree of uncertainty and potential risk.

The National Fire Danger Rating System (NFDRS) produces indexes that assess fire danger for large areas (Deeming and others 1977). The Fire Management Policy Review Team (USDA, USDI 1989) recommended that NFDRS indexes be considered part of a comprehensive set of criteria in deciding whether or not to allow natural ignitions to burn as prescribed fires.

The prescription will include a list of important questions, such as:

- Are there threats to life and property?
- Are funds available?
- Are there defensible boundaries given expected fire behavior?

We, however, focus only on the role that NFDRS plays in the prescribed natural fire decision process, keeping in mind that it is only one of many factors to be considered.

## DECISION TIMEFRAMES

Several stages are involved in prescribed natural fire decisionmaking; additional information is available at each stage. Time frames with respect to the ignition are: a year or more before the ignition, during the fire season before the ignition, shortly after the ignition, and after the fire has been designated a prescribed natural fire.

A year or more before the ignition, fire management plans are written and prescription criteria are developed. The information available then includes a history of weather, danger rating indexes, and historical fire occurrence and size for the area. The NFDRS percentile levels, often the 90th or 97th percentiles, have been used to define critical levels of fire danger. The NFDRS percentile levels can be better interpreted if they are related to fire history.

Futuring can be an important step in prescribed natural fire decisionmaking. An evaluation of the prescribed natural fire program in the Selway Bitterroot Wilderness (Brown and others 1995) found that the prescribed natural fires that exceeded 100 acres burned for an average of 3 weeks before their most active burning phase. The fire season can be tracked by plotting and comparing the NFDRS levels to critical levels, to past seasons, to historical average levels and to extreme levels. In addition, potential fire danger can be calculated into the future for several weeks based on various weather scenarios such as: hot and dry with 80 percent nighttime humidity recovery, hot and dry with 100 percent nighttime humidity recovery, cool and wet like August 1987 (fig. 1).

Long-range fire weather forecasts might also be used (McCutchan and others 1991). Based on the level of current and potential fire danger and the criteria in the prescription, prescribed natural fire may not even be an option.

Shortly after the ignition is reported, managers must make the go/no-go decision. The fire is declared either to be a wildfire or a prescribed natural fire. Most of the assessment based on the NFDRS is already complete, allowing fire managers to concentrate on other issues like fire behavior prediction. Plots of NFDRS levels and analysis of their significance can be shown to decisionmakers.

After the fire has been designated a prescribed natural fire, the fire and conditions are monitored to assure it remains in prescription. The NFDRS level is compared to critical levels. "What if" weather projections allow a range of potential fire danger to be forecast for the next several weeks. Fire danger displays can be used to explain the situation to the public and to brief line officers.

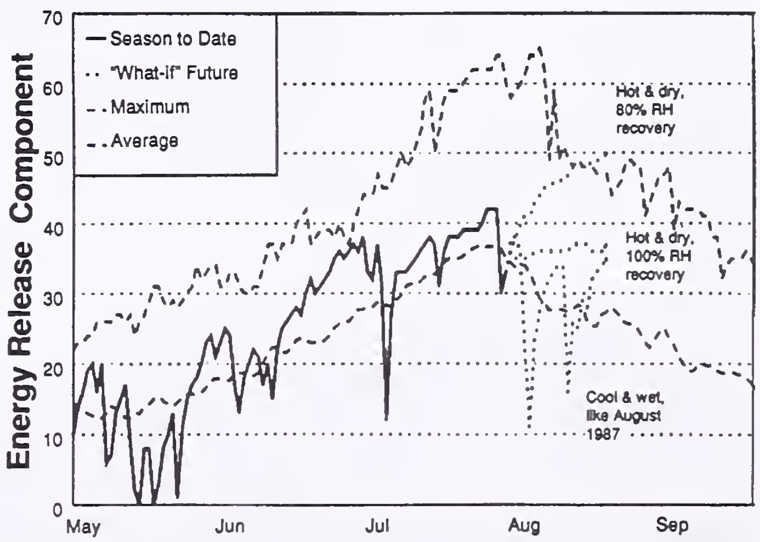


**Figure 1**—Energy Release Component (ERC) seasonal plot this season to date with historical maximum and average values for comparison. "What-if" weather for 20 days into the future under three scenarios; RH stands for relative humidity.

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## NATIONAL FIRE DANGER RATING SYSTEM OVERVIEW

The NFDRS provides a rating for a general area rather than for a specific fire location. Fire danger rating can play an important role in prescribed natural fire decision-making. But it is necessary to know the system's scope and capabilities; don't expect it to do things it can't do. The NFDRS level reflects general weather patterns based on afternoon weather observations at fixed stations, often in valley bottoms. The system was designed to reflect severe conditions that may not occur on other sites. Fire danger rating cannot be used to predict the behavior of a specific fire. Other tools such as fire growth simulation (Andrews and Bevins, this proceedings) should be used for site-specific fire behavior.

Figure 2 is a diagram of the National Fire Danger Rating System, showing information used in calculating each index. Note that wind is used to calculate Spread Component, but not Energy Release Component; and that most of the emphasis is on the fine fuels for Spread Component and on the heavier fuels for Energy Release Component. Therefore, if the fuel model includes heavy fuel (100-hour and 1,000-hour timelag fuels), the Energy Release Component reflects seasonal drying and wetting trends. The Energy Release Component based on fuel models without the 100-hour and 1,000-hour categories has no "memory" of past weather; it is based only on each day's weather observations with no carry over from the previous day (except in live fuel moisture). Keetch Byram Drought Index (KBDI) has also been suggested as an indicator of seasonal drying (Burgan 1988). Precipitation amount and maximum temperature are the only daily weather values used in calculating the Keetch Byram Drought Index; fuel type is not a consideration.

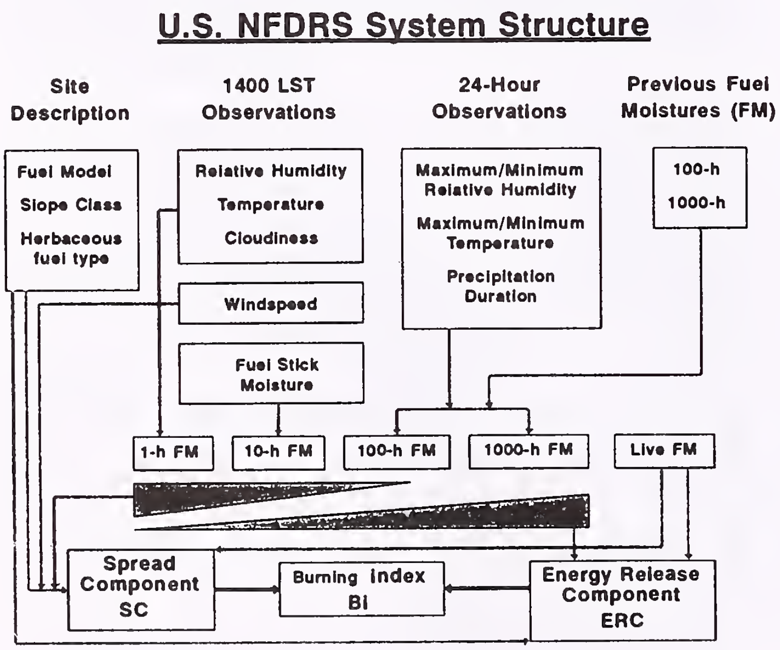


**Figure 2**—Structure of the National Fire Danger Rating System (NFDRS) showing the relationship among site description, weather observations, intermediate fuel moisture (FM) calculations, and the final indexes. The "LST" in "1400 LST observations" stands for Local Standard Time.

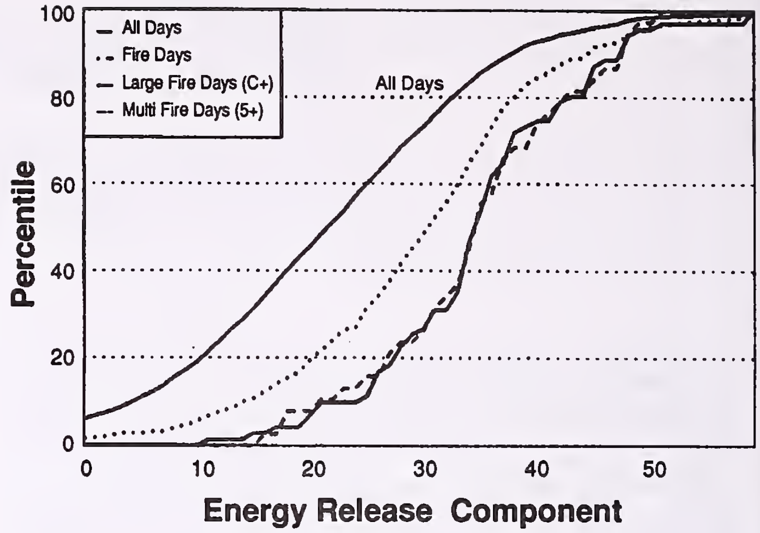


**Figure 3**—Precentile curves for all days, fire days, large fire days (days when a fire started that eventually burned more than 100 acres), and multiple fire days (days when five or more fires started) for the Moose Creek weather station and fires in the Selway-Bitterroot Wilderness.

## DEFINING CRITICAL LEVELS

A strength of the fire danger rating system is its use in historical calculations. It is possible to compare the current year with past years as well as with maximum and average values. If fire occurrence and size are related to index values even more information is available for setting critical levels for the prescription. We define a "fire day" to be a day on which a fire was discovered, a "large fire day" as a day on which a fire of final size over 10 acres was discovered, and a "multiple fire day" to be a day on which five or more fires were discovered.

For the example in this paper we use fires from 1972 to 1989 in the 1.2 million-acre Selway-Bitterroot Wilderness in central Idaho and western Montana. Weather observations used in the NFDRS calculations are from the Moose Creek Ranger Station, located in the northern section of the wilderness.

A common way of looking at historical fire danger is by percentiles. Percentiles can be developed for fire days, large fire days, and multiple fire days as well as for all days. Note in figure 3 that only 7 percent of the days had an Energy Release Component over 40, but 16 percent of the fire days and 27 percent of the multiple fire days occurred when it was over 40.

Another way to relate fire danger to fire history is to use logistic regression (Loftsgaarden and Andrews 1992). Figure 4 shows curves for the probability of a fire day, large fire day, and multiple fire day as a function of Energy Release Component. The probability of a fire day is 18 percent when the Energy Release Component is 30 and 41 percent when it is 50. Probability of a large fire day increases from 3 to 11 percent as the Energy Release Component goes from 30 to 50.

Table 1—Number and percent of days in each Energy Release Component (ERC) class

| ERC | All days | | Fire days | | Large fire days | | Multiple fire days | |
|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % |
| 0-15 | 969 | 31 | 47 | 11 | 2 | 4 | 0 | 0 |
| 16-30 | 1,298 | 42 | 163 | 37 | 15 | 30 | 10 | 26 |
| 31-40 | 614 | 20 | 158 | 36 | 24 | 48 | 18 | 47 |
| 41-50 | 174 | 6 | 51 | 12 | 8 | 16 | 9 | 24 |
| > 50 | 43 | 1 | 16 | 4 | 1 | 2 | 1 | 3 |
| Total | 3,098 | 100 | 435 | 100 | 50 | 100 | 38 | 100 |

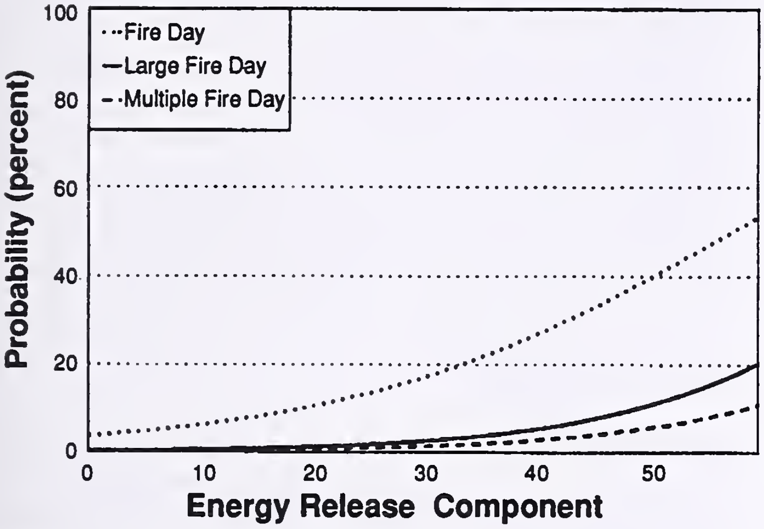


**Figure 4**—Probability of fire days, large fire days (days when a fire started that eventually burned more than 100 acres), and multiple fire days (days when five or more fires started) from logistic regression based on the same data as figure 3.

Table 1 shows the data for five levels of fire danger based on figure 3. Table 2 gives selected probability values from figure 4. Information from both the percentile and probability curves can be used to define critical levels for the go/no-go decision for prescribed natural fire.

**Table 2**—Probability from logistic regression for selected Energy Release Component (ERC) values

| ERC | Fire-day probability | Large-fire-day probability | Multiple-fire-day probability |
|---|---|---|---|
| | | *Percent* | |
| 15 | 8 | 0 | 0 |
| 30 | 18 | 3 | 1 |
| 40 | 28 | 5 | 3 |
| 50 | 41 | 11 | 6 |

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# Quantifying Historic Fire and Forest Patterns

**Stephen F. Arno**
**Elizabeth D. Reinhardt**
**Joe H. Scott**

In lodgepole pine/subalpine fir forests of the Northern Rockies, fires and mountain pine beetle outbreaks have recurred continually for thousands of years. Each disturbance initiated new successional cycles and landscape patterns. Recently, National Forest managers have attempted to assess the effects of fire suppression and logging on landscape biodiversity and wildlife habitat in these forests. We developed a method for documenting forest structure and landscape pattern in this forest type. The method consists of laying out a systematic grid on the landscape and sampling forest structure and disturbance history at each grid point. Using our analysis procedures, current and past landscapes can be compared in terms of species composition and stand structure.

We developed and applied this method on a 500-acre tract of lodgepole pine/subalpine fir forest in the Bitterroot National Forest. Here, this procedure revealed a surprisingly complex spatial mosaic linked to disturbance history as well as a pronounced successional advance toward climax during this century. A detailed description of field procedures as well as recommendations for data synthesis and interpretation are presented in Arno and others (1993).

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# Historical Fire Occurrence in Remote Mountains of Southwestern New Mexico and Northern Mexico


## Christopher H. Baisan
## Thomas W. Swetnam


It has long been held that ponderosa pine forests in the Southwestern U.S. were not subject to crown fires in the pre-settlement era (around 1880). Many authors, including Leopold (1924), Weaver (1951), and Cooper (1960) have convincingly argued this point; they have also discussed the negative consequences of withholding fire from these forests, such as an increasing hazard of stand-replacing crown fires due to excessive accumulation of live and dead fuel. However, it may be that mountainous areas with sharp relief and low lightning ignition rates or poor fuel continuity tend toward unstable disturbance regimes; they may experience an increased incidence of stand-replacing fires in forest types which would not typically support such events. Plant communities in such areas may be relatively transitory compared to communities in areas comprised of large homogeneous blocks and gentle topography. The Basin and Range Province of southern Arizona/New Mexico and northwestern Mexico is populated by numerous isolated mountain ranges of varying size and topography. Fire regimes in these ranges have been little studied and may not be adequately characterized by current models of surface fire versus crown fire regimes.

This paper presents preliminary results and implications of ongoing fire-history research in the borderlands region of southwestern New Mexico and southern Arizona and in the Mexican States of Chihuahua and Sonora. The objective of this study is to document and compare fire regimes in paired island mountain ranges on both sides of the international boundary, a sparsely populated region where fire control has had limited impact. In the first phase of this work we collected and analyzed 68 fire-scarred sections from the Animas Mountains in New Mexico. Results of previous work in the Sierra de los Ajos of Mexico are presented for comparison.

## SITE DESCRIPTION

The Animas Mountains, rising to 2,634 m, extend over a 100-square-kilometer area in the Gray Ranch of southern Hidalgo County, NM (Fig. 1). The mountains' proximity to both the Sierra Madre and the Southern Rockies has resulted in a floristically diverse vegetation comprised of both northern and southern elements. Mixed conifer stands similar to those of the Southern Rockies grade into oak-pine forest, oak woodlands, and savannah typical of the Sierra Madre. Topographic complexity interacting with the fire regime has resulted in a mosaic of plant communities largely determined by aspect and elevation with only relatively mesic canyons and northeast facing slopes supporting well-developed coniferous forest. Chaparral, oak scrub, and stands of pinyon-juniper are found on the drier aspects. Foothill areas support grassland and oak savannah. A lightning fire in the second half of June 1989 (the driest year in this area since 1956) burned unrestricted for most of a week and spread over 11,000 ha of the Animas range before it was halted by suppression efforts.

The Sierra Ajos are an isolated mountain range in northern Sonora, Mexico. They rise above 2,600 m and the upper elevations support coniferous forest. The fire chronology presented here was developed from a pine stand near the center of the range. Planned collection efforts will update and extend this chronology.

## METHODS

For this portion of the study, 68 fire-scarred cross sections and numerous increment cores were collected in the Animas range. Sections were primarily collected from dead material: logs or snags. A limited number of living trees were sampled by removing partial wedge sections as described by Arno and Sneck (1977). All samples were surfaced to a high polish for examination with a binocular microscope; calendar dates and a seasonal designation were assigned to fire events (Baisan and Swetnam 1990). Fire dates were compiled into a master fire chronology in order to examine their spatial and temporal distribution. Results of the previous study in the Sierra Ajos (Swetnam 1983) were re-compiled and analyzed as well.

## RESULTS AND DISCUSSION

The reconstructed fire history of the Animas Mountains (Fig. 2) provides unique insights into the interaction of fuels, vegetation, topography, and land use history in the regulation and perpetuation of fire regimes on an isolated mountain range. Based on dendrochronological (tree-ring) dating of remnant snags and logs in some of our sampled stands, we hypothesize that patchy, stand-replacing fires, similar to the 1989 fire, also occurred in 1707, 1805, 1825,


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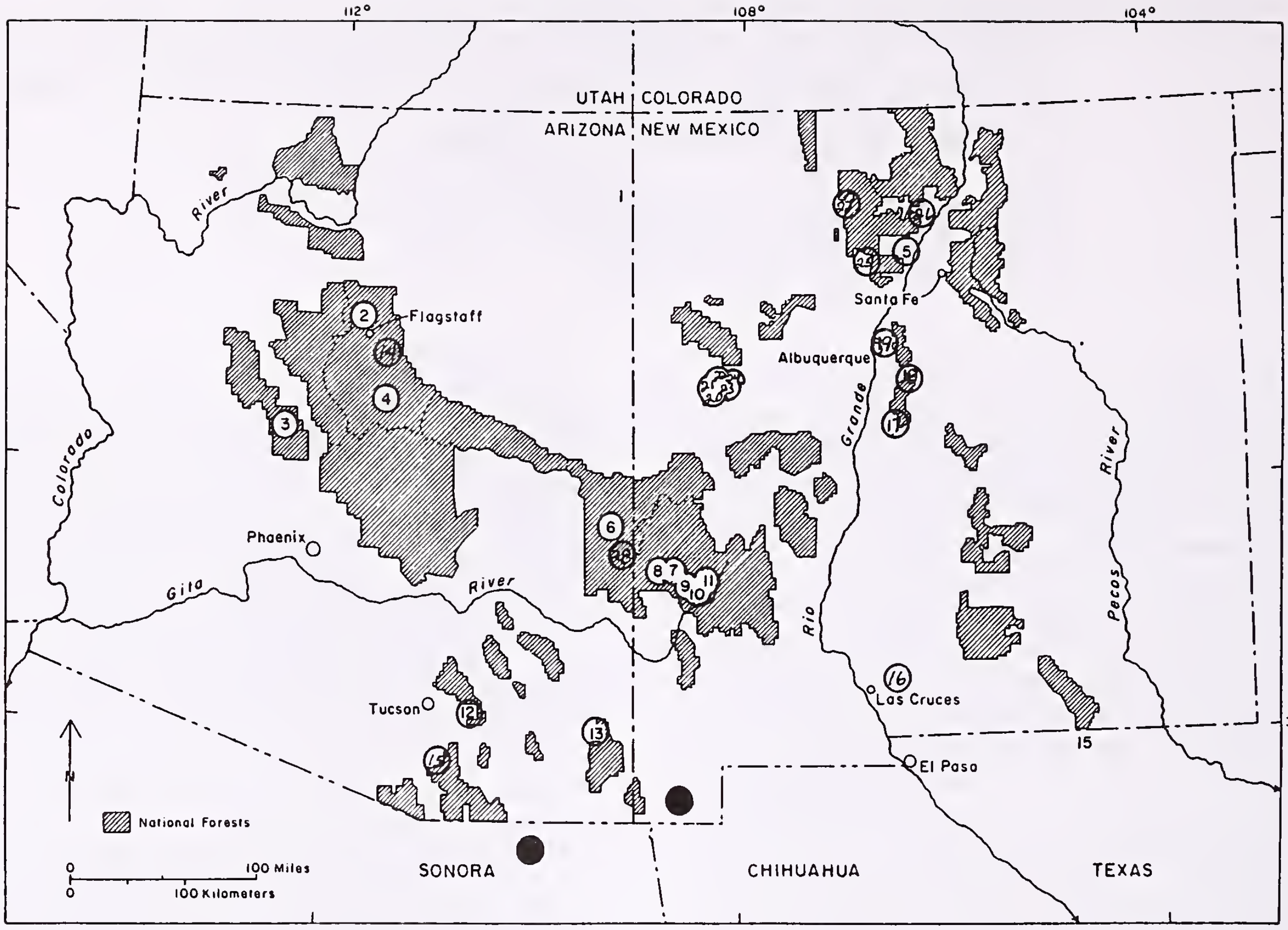


**Figure 1**—Map of fire history collection sites in Arizona, New Mexico, and northern Mexico. The Animas Mountains and the Sierra Ajos are marked with black dots.

1857, and 1879. Lack of old-appearing individuals in the current canopy of some stands suggests that they regenerated following these events. Portions of these stands sustained crown fire in 1989. A concurrently funded companion study of stand structure may provide additional data for testing this hypothesis.

The Forest Service had jurisdiction of the Animas Mountains from approximately 1909 to 1957. This is clearly evident in the fire chronology as a period of reduced fire activity. Also note the return of spreading fires in 1959, just two years later. Although the lower slopes, grassland, and to a limited extent the high country, have been grazed, probably since the 1890's, it is not clear what impact this land use has had on the fire regime as distinct from the active fire suppression practiced by the Forest Service.

Lightning ignited a fire on June 15, 1989, in the foothills along the north margin of the Animas Mountains (Smith 1993). The fire burned up into the main body of the range and continued to spread for most of a week before suppression efforts were effective. The fire eventually spread over the northern two-thirds of the range and through the whole array of plant communities from grassland to upper-elevation forests. Fire effects varied from light-intensity surface burn to total destruction of the forest canopy and understory vegetation. The final size exceeded 11,000 ha; the fire continued to burn within the controlled perimeter for more than a month. By 1992 the oak brush and chaparral communities were regenerating vigorously while forested areas, including pine, mixed conifer and pinyon-juniper stands, which experienced canopy destruction, remained denuded except for annual forbs. Soil was eroding on some of the steeper slopes in these areas.

Visual observations of stand structure, combined with dates of death of canopy trees and the reconstructed fire chronology, provide evidence of a mixed surface fire/crown fire disturbance regime for the Animas range. The combination of rugged topography, heterogeneous vegetation (including large areas of oak brush and chaparral which support fires only infrequently), and relatively low ignition rate resulted in relatively long fire-free periods for individual stands. A pattern of infrequent surface fires was evidently punctuated by a canopy-replacement fire in some stands every century or two, especially areas within the interior of the range and those occupying relatively mesic sites. Thus, viewed in historical context, the 1989 fire was not an unprecedented event, but reflected the continuation of a long-term pattern. Although the fire regime of the Animas Mountains was disrupted by a 50-year period of fire suppression, the continued occurrence of surface fires in some stands during this century clearly diminished the overall impact of a fire which occurred during an exceptionally dry year. We suspect that mixed surface fire/crown fire regimes may have occurred in other mountain ranges with similar rugged topography in the Southwestern United States, northern Mexico, and perhaps the Great Basin. Further research may begin to

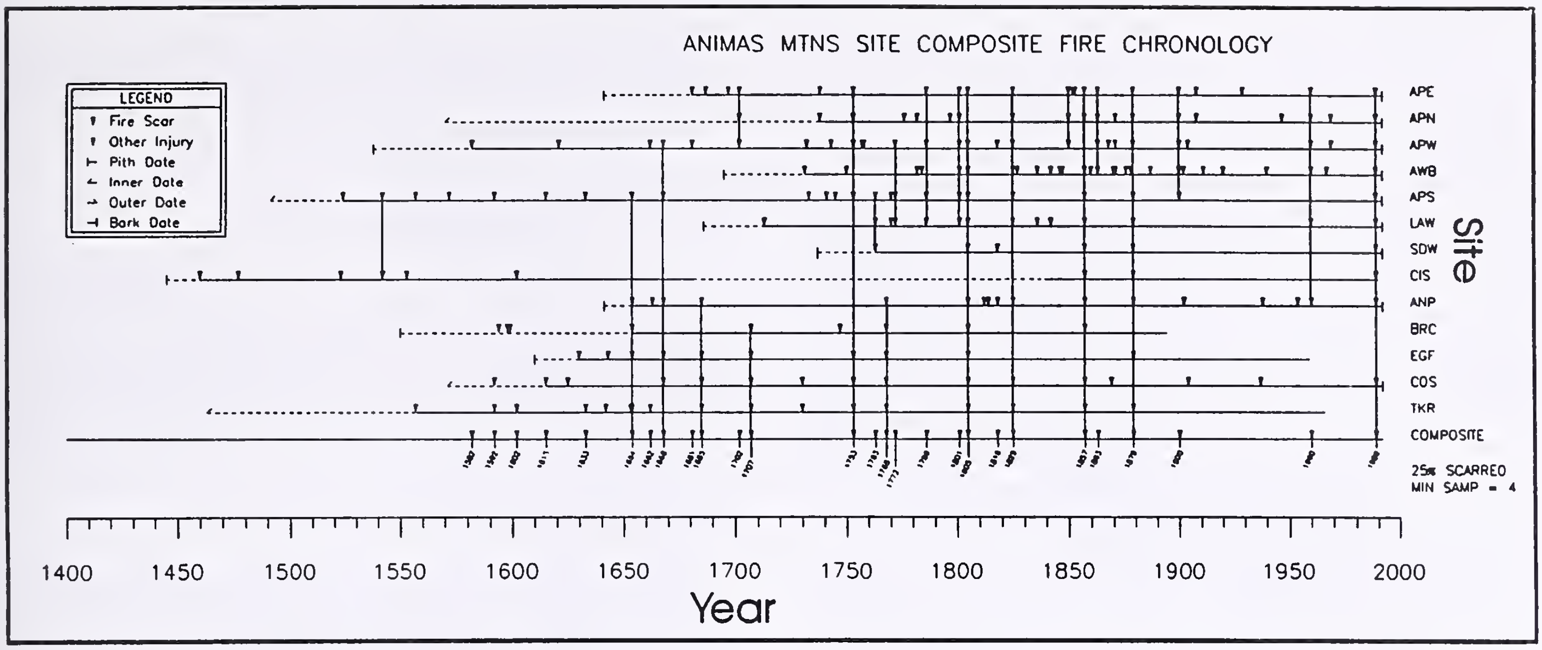


**Figure 2**—Composite fire chronology chart for the Animas Mountains. Horizontal lines represent sampled life spans of trees at each site, and arrowheads denote fire dates recorded at each site. Note the evidence for episodic spreading fires in the vertical alignment of arrowheads in 1668, 1753, 1805, 1825, and 1879.

clarify and define relationships between fire regimes and landscape factors.

By contrast, the fire regime of the Sierra Ajos has not experienced the disruptive influences of fire control and intensive grazing (Fig. 3). The uninterrupted occurrence of fires during this century is not found north of the border except in a few areas completely isolated from management and utilization. Additionally, the fire regime at this site is more representative of those typically studied in the ponderosa pine type. The mean fire interval here was 5.4 yr, well within the range reported for ponderosa pine in the Southwest. Ongoing work will more completely characterize the range of variability in this location and determine whether this stand is representative of this mountain range.

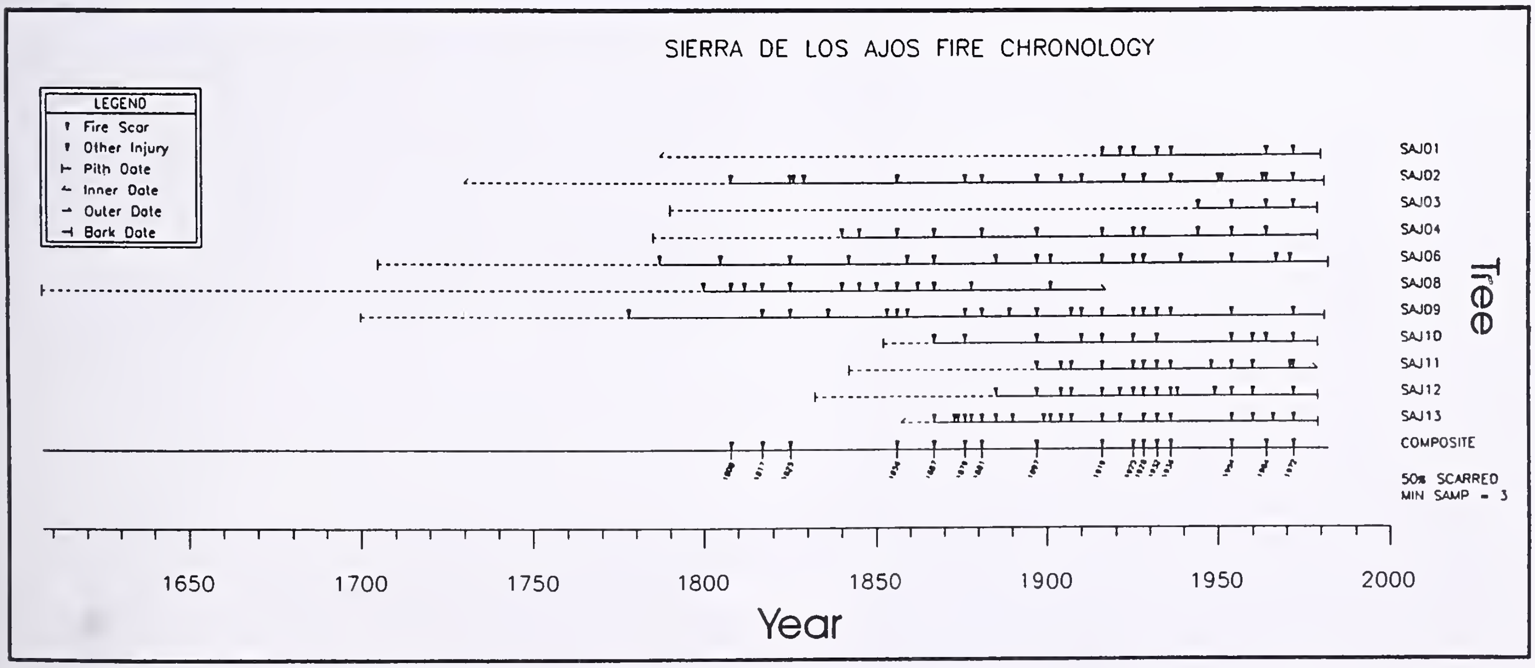


**Figure 3**—Fire chronology chart for the Sierra de los Ajos. This mountain range is 30 km south of the United States-Mexico border. Fire frequency here was more typical of southwestern pine forests, but the continuous history of episodic fires throughout the twentieth century is rarely observed on the northern side of the border. Nearly all Southwestern United States surface fire regimes were initially impacted around the turn of the century by intensive livestock grazing, and subsequently, fire suppression (see papers by Touchan and Swetnam, and Grissino-Mayer and Swetnam).

## SUMMARY

The Animas Mountains appear to have maintained a meta-stability resulting from this mixed surface/canopy fire regime for at least the past four to five centuries. Although individual stands of conifers and shrubs were intermittently destroyed by crown fire, in the larger context of the mountain range, many other stands survived. In between the infrequent, intense fires, lower intensity fires served to reduce fuels in some stands, affording them long-term resistance to crown fires. This example provides hope that the current situation in semi-arid western wilderness areas with large amounts of woody fuels and excessive regeneration due to eight decades of fire suppression can be successfully managed by a strategy of planned ignition under moderate climatic conditions coupled with the tolerance for heterogeneous burning including some canopy loss. This tolerance is a prerequisite for planning and successfully treating any sizeable area (larger than 500 ha), given the reality of budgetary and manpower constraints.

## CONCLUSIONS

This historical analysis provides some historical perspective and recommendations for land managers of these rugged, isolated mountain ranges of the Southwest.

- Despite the occurrence of high-intensity fires in the past, the overall community structure of the Animas Mountains appears to be stable; loss of individual stands apparently has not resulted in loss of species or communities.
- Pre-treatment by planned ignition of areas of some reasonable size (larger than 500 ha) will help break up fuel continuity and provide buffering for wildfires occurring under extreme conditions.
- Creating a mosaic of burned and unburned areas may provide sufficient refugia to maintain existing diversity through natural regeneration, even if large wildfires subsequently occur under extreme conditions.

## ACKNOWLEDGMENTS

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# Three Contrasting Fire Regimes in Yellowstone National Park

Stephen W. Barrett
Stephen F. Arno

To date, three distinct fire regimes have been identified in Yellowstone National Park. Before 1900 in the Park's Northern Range (fig. 1), Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) stands bordering dry valley grasslands (38 cm mean annual precipitation) experienced light surface fires at 20 to 50 year intervals (Barrett 1994; Houston 1973). Surface fires maintained very open stands in the Park's northern valleys. This finding is similar to those for other high-elevation valleys in the Northern Rockies, where individual multiple-scarred Douglas-firs often exceed 500 years of age (Arno and Gruell 1983, 1986; Loope and Gruell 1973).

Conversely, very infrequent stand-replacing fires have occurred on the park's subalpine plateaus (Romme 1982). Here, the lodgepole pine-whitebark pine (*Pinus contorta-P. albicaulis*) forest grows very slowly in response to a cold-dry climate (48 cm mean annual precipitation) and droughty infertile soils (Despain 1990). Consequently, the slow fuel accretion can promote stand-replacement burning after 300 to 400 years, similar to Romme and Knight's (1981) finding for infertile sites in Wyoming's Medicine Bow Mountains.

Substantially shorter intervals have occurred in lodgepole pine stands in Yellowstone National Park's Absaroka Mountains (Barrett 1994). More productive sites, in combination with greater mean annual precipitation (69 cm) and steeper terrain promote stand-replacing fires after 150 to 250 years. This finding is similar to results for relatively productive lodgepole pine stands on mountain terrain elsewhere in the Northern Rockies (Arno 1980; Barrett and others 1991; Barrett 1993a,b).

During the severe 1988 fire season, many overmature stands were replaced in the three study areas. Stand-replacement burning in 1988 was primarily a natural event in lodgepole pine. However, a century of fire suppression contributed to replacement burning in Douglas-fir stands that had developed accumulations of live and dead understory fuels.


**Figure 1**—Location of three fire history study areas, Yellowstone National Park.

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# Fire Adaptations in Pines and Oaks: Tree Population Responses to Fire Suppression in Arizona's Madrean Forests

Andrew M. Barton

Fire is a primary factor controlling forest community composition and succession in western North America (Wright and Bailey 1982). Little is known, however, about the role of fire in the Madrean vegetation that covers portions of the mountains in southern Arizona, New Mexico, and Mexico. Land managers and ecologists have called for investigation of the fire ecology of these areas in order to evaluate alterations caused by 75 years of fire suppression and to develop ecologically based fire management plans (Ffolliott and Lefevre 1988; USDI National Park Service 1992).

Such plans require documentation of the consequences of various fire regimes, including suppression and "natural" fire patterns, for populations of tree species (Christensen 1988). Because tree species have evolved several contrasting strategies for persisting in fire-prone environments (McCune 1988), it is crucial to understand differences among species in response to fire and the consequences of these differences for vegetation composition.

In this paper, I report on contrasts in fire adaptation between pine and oak species in mid-elevation Madrean forests in southeastern Arizona and on the consequences of these differences for the effects of fire suppression versus more natural fire regimes. In these forests, fire suppression has greatly increased densities of oaks, especially silverleaf oak (*Quercus hypoleucoides*), possibly at the expense of pines (Marshall 1957; USDI, National Park Service 1992). I examined whether this pattern has resulted from contrasts in fire adaptations: fire resistance in pines versus post-fire resprouting in oaks. First, I tested the hypothesis that, in response to fire, pines exhibit higher stem survival than oaks, but when top-killed, resprout less than oaks. Second, I examined the effects of increased canopy biomass and litter depth, resulting from fire suppression, on pine and oak seedling establishment.

## METHODS

### Study Area

I worked primarily in the Chiricahua Mountains, which are located in southeastern Arizona (31° 52' N, 109° 15' W). The range extends southeast to northwest for about 80 km and rises from about 1,100 to 3,000 m altitude. The climate is semi-arid with two wet seasons: one between July and September, when more than 50% of total precipitation falls, and the second between December and March. A pronounced dry season usually occurs between the final winter storms in March or April and the onset of the rainy season in July (Sellers, Hill, and Sanderson-Rae 1985).

The vegetation of the Chiricahuas is diverse in terms of species and habitats, at least in part because of the mixing of species and environments from the Rocky Mountains to the north and the Sierra Madre to the south. Vegetation changes markedly from low to high elevations, as follows: desert scrub, desert grassland, open oak woodland, pine-oak woodland, pine-oak forest, pine forest, montane fir forest, and subalpine forest (Niering and Lowe 1984; Barton 1991).

In the western Chiricahuas (Rhyolite Canyon) in pine and oak vegetation, the mean fire return intervals before 1801 ranged from 6.2 to 14.6 years (Swetnam and others 1989). Fires of lightning origin peak in frequency in July just prior to the height of the monsoon season, but the area burned peaks in June (Barrows 1978; Baisan and Swetnam 1990; A. M. Barton unpublished). Since the late 1800's, fires have been largely suppressed (Swetnam and others 1989).

## Responses of Tree Populations to Fire

During March and April 1992, I investigated the responses of tree populations to fire in five pine-oak sites where fires had burned in the past 10 years. In the Chiricahuas, I sampled two management-ignited prescribed fires in Rhyolite Canyon: a 4-ha fire from 22 September 1986 (Rhyolite T fire) and a 32-ha fire from 19 August 1982 (Rhyolite III). I also sampled two sites (opposite sides) of the 23-ha, 4 June 1983 Methodist wildfire in Pine Canyon in the Chiricahuas and the larger than 10,000 ha summer 1989 wildfire in the Animas Mountains, New Mexico (within 50 km of the Chiricahuas).

For each burn, I chose areas where fire had top-killed some, but not all, of the canopy trees and sampled either the entire area or along transects 5 to 10 m wide and of variable length, depending on the size of the chosen area. I documented survival or death resulting from fire and the d.b.h. of all stems 1.4 m tall or taller, the species of these stems (based on distinguishing traits not modified by fire), whether or not top-killed stems had resprouted, the number of sprouts per top-killed stem (few, intermediate, or many sprouts), the height of the tallest sprout for each top-killed tree, and the number and height of pine and oak seedlings.

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## Effects of Fire Suppression on Seedling Establishment

During October and November 1991, I investigated the effects of increased canopy cover and litter depth, resulting from fire suppression, on pine and oak seedling establishment in two unburned pine-oak sites in the Chiricahua Mountains. One study area was in the Cave Creek drainage, in the Coronado National Forest, within 5 km of the Southwestern Research Station. Elevations were 1,820 to 1,920 m, aspect was generally northwest, slopes were about 5 to 30%, and soils were monzonite-derived. The second study area was in Rhyolite Canyon in Chiricahua National Monument. Elevations were 1,675 to 1,750 m, aspects were generally west to southwest, slopes were less than 10%, and soils were rhyolitic tuff-derived. Table 1 shows the dominant tree species in the two sites.

In each area, ten 50- by 5-m plots were randomly chosen according to elevation along a transect. Each plot was subdivided into ten 5- by 5-m subplots. In each subplot, I documented percent canopy cover 1.4 m tall or taller (at five stratified points, with a spherical densiometer), litter depth (at 16 stratified points), percent cover of silverleaf oak less than 1.4 m tall (at 100 stratified points), number and species of seedlings (less than 1.4 m tall) of pines, and d.b.h. and species identity of all stems 1.4 m tall or taller. Because of the very high local density of silverleaf oak resprouts, percent cover rather than density was used to assess juvenile abundance of this species. Data were analyzed with multiple regression in the Procedure, "Proc Mixed," of Statistical Analysis System (SAS Institute, Inc. 1992), which takes into account the spatial proximity and possible lack of independence among subplots within each plot. Analyses including seedling abundance combined adjacent subplots (into 5- by 10-m areas, for instance) to avoid an excessive number of subplots with zero values.

## RESULTS

### Responses of Tree Populations to Fire

Pine species exhibited higher percent top survival through fire than did oak species (Table 2). Within each genus, however, there were also significant differences among species (Table 2). Species with higher top survival had thicker bark (Barton, unpublished). Percent resprouting after top-kill was significantly higher in oaks than in pines (Table 3). Again, there were significant differences in resprouting response within each genus (Table 3). Within the pines, only Chihuahua pine resprouted, but its resprouting response was poorly developed compared to that of the oaks. Similarly, in terms of number of resprouts per original stem, there were significant differences among oak species, but all oaks outperformed the weakly resprouting Chihuahua pine ($p < .05$, pairwise $G$-tests using Bonferroni probabilities; data not shown).

Tables 2 and 3 together suggest that species with high stem survival were poor at post-fire resprouting and that species with poor stem survival were good at post-fire resprouting. The probable continuum from good fire resisters to good resprouters is: Apache pine, Chihuahua pine, Arizona white oak, Emory oak, silverleaf oak, and netleaf oak. In fact, using the three fires in which at least five species occurred, fire resistance of shoots and percent resprouting were significantly negatively correlated among species ($r = .87$, $p < .03$; Figure 1), despite the small sample size of species. For the same data set, percent top survival was also negatively correlated with the number of sprouts produced per stem ($r = .88$, $p < .03$; data not shown).

Resprouts were consistently much taller than seedlings in the same burn ($F$-test, $p < .01$ for each species). The smallest difference between these two stem classes was for Emory oak (means of 143.4 versus 41.9 cm) and the largest was for Chihuahua pine (means of 175.7 versus 16.0 cm).

### Effects of Fire Suppression on Seedling Establishment

Fire suppression typically increases tree biomass, which by increasing litter depth and canopy cover (lowering light), reduces seedling establishment (Wright and Bailey 1982). Accordingly, I examined the relationships among these variables. Litter depth increased with increasing tree basal area ($F_{1,178} = 21.9$, $P < .001$) and density ($F_{1,178} = 7.2$, $P < .008$). In multiple regressions in which silverleaf oak and other species were separated as independent variables, litter depth was positively related to oak density ($F_{1,176} = 10.4$, $P < .002$). Percent canopy cover (>1.4 m height) was positively related to tree density ($F_{1,178} = 4.4$,

**Table 1**—Dominant tree species (percent of total) in two study sites in the Chiricahua Mountains

| Species | Cave Creek Canyon Basal Area | Cave Creek Canyon Stems | Rhyolite Canyon Basal Area | Rhyolite Canyon Stems |
|---|---|---|---|---|
| | *Percent* | | | |
| Silverleaf oak (*Quercus hypoleucoides*) | 59.1 | 88.6 | 31.6 | 52.3 |
| Arizona white oak (*Q. emoryi*) | 2.8 | 2.6 | 18.2 | 15.2 |
| Chihuahua pine (*Pinus leiophylla*) | 22.5 | 3.9 | 29.9 | 4.9 |
| Apache pine (*P. engelmannii*) | 13.6 | 2.5 | 5.3 | 1.7 |
| Arizona cypress (*Cupressus arizonica*) | 0.0 | 0.0 | 10.3 | 14.1 |

**Table 2**—Percent top survival through fire of stems (>1.4 m tall) for pine and oak species. Sample sizes are given in parentheses. Values without the same underlining are significantly different ($p < .05$, pairwise $G$-tests using Bonferroni probabilities). Species are aligned from left to right in decreasing order of fire resistance

| Fire | PE* | PL | QA | QE | QH | QR |
|---|---|---|---|---|---|---|
| Rhyolite T | 57.1 (14) | 56.0 (25) | 54.8 (104) | 33.3 (21) | 19.7 (218) | |
| Rhyolite III | 100.0 (12) | 77.8 (27) | 73.9 (69) | 28.0 (25) | 21.2 (52) | |
| Methodist #1 | 67.1 (82) | 27.9 (79) | 25.4 (63) | 0.0 (214) | 0.5 (200) | |
| Methodist #2 | 86.2 (29) | 44.8 (29) | | | 15.1 (292) | 0.0 (17) |
| Animas Mts. | | 68.9 (103) | | | 16.7 (442) | 0.0 (66) |

*PE, Apache pine; PL, Chihuahua pine; QA, Arizona white oak; QE, Emory oak; QH, silverleaf oak; QR, netleaf oak.

**Table 3**—Percent of stems resprouting after top kill for pine and oak species. Sample sizes are given in parentheses. Values without the same underlining are significantly different ($p < .05$, pairwise $G$-tests using Bonferroni probabilities). Species are aligned from left to right in decreasing order of resprouting ability

| Fire | PE* | PL | QA | QE | QH | QR |
|---|---|---|---|---|---|---|
| Monument #1 | 0.0 (6) | 0.0 (11) | 29.8 (47) | 71.4 (14) | 46.3 (175) | |
| Monument #2 | | 0.0 (5) | 50.0 (18) | 27.8 (18) | 36.6 (41) | |
| Methodist #1 | 0.0 (27) | 27.4 (73) | 48.9 (47) | 87.5 (16) | 60.3 (199) | |
| Methodist #2 | 0.0 (4) | 6.3 (16) | | | 48.4 (248) | 29.4 (17) |
| Animas Mts. | | 12.5 (32) | | | 29.1 (368) | 40.9 (66) |

*PE, Apache pine; PL, Chihuahua pine; QA, Arizona white oak; QE, Emory oak; QH, silverleaf oak; QR, netleaf oak.

$P < .04$), but not to basal area ($F_{1,178} = 2.7$, $P = .11$). Basal area ($F_{1,175} = 3.4$, $P = .07$) and density ($F_{1,175} = 3.1$, $P = .08$ of silverleaf oak were positively related to percent cover, but these relationships were marginally nonsignificant.

For each pine species, increasing litter depth reduced seedling abundance (Apache pine: $F_{1,77} = 10.48$, $P < .002$; Chihuahua pine: $F_{1,77} = 13.1$, $P < .001$). Percent cover and seedling abundance were negatively related in Chihuahua pine ($F_{1,77} = 6.5$, $P < .013$), but not in Apache pine ($F_{1,77} = 0.6$, $P = .84$). In contrast, percent cover of silverleaf oak juveniles was unaffected by levels of litter depth ($F_{1,78} = 1.5$, $P = .23$) and percent cover ($F_{1,78} = 0.6$, $P = .44$).

Seedling abundance was negatively related to total tree density in Apache pine ($F_{1,75} = 5.9$, $P < .02$; Figure 2) and to both tree density ($F_{1,77} = 1.6$, $P = .10$; Figure 2) and tree basal area in Chihuahua pine ($F_{1,77} = 3.7$, $P < .03$). In contrast, juvenile cover of silverleaf oak actually increased with increasing tree density ($F_{1,77} = 13.5$, $P < .001$; Figure 2). In multiple regressions in which silverleaf oak and other species were separated as independent variables, oak density was negatively related to seedling density in Apache pine ($F_{1,70} = 9.2$, $P < .003$) and Chihuahua pine ($F_{1,70} = 4.5$, $P < .04$), but positively related to silverleaf oak juvenile cover ($F_{1,70} = 15.8$, $P < .001$).

## DISCUSSION

The results point to fire resistance and post-fire resprouting as contrasting strategies between pines and

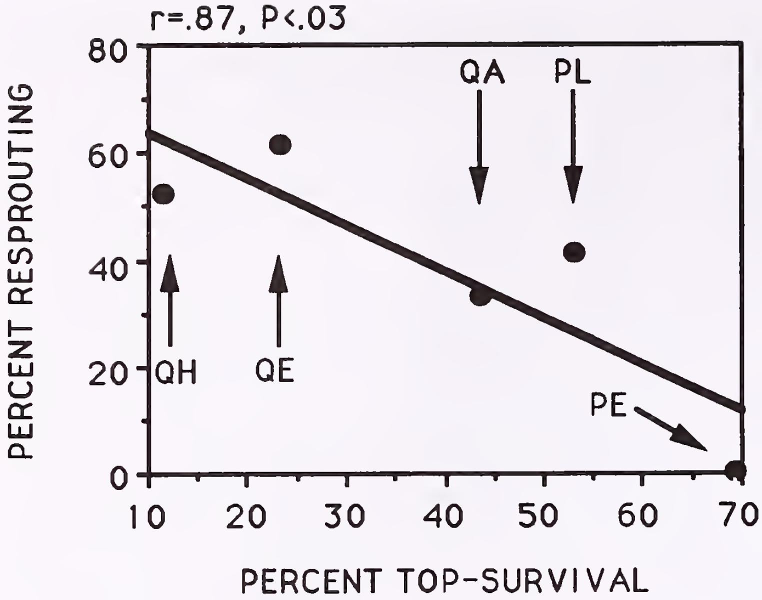


**Figure 1**—Correlation between percent top survival and percent post-fire resprouting among three oak and two pine species in three fires combined in the Chiricahua Mountains. Species symbols are given in Tables 1, 2.

oaks, respectively, for persisting in this fire-prone environment. The results suggest further that across all species, regardless of genus, these two responses are negatively correlated (Figure 1). At one extreme were species, mainly pines, with shoots well-adapted for surviving fire, but with limited or no ability to resprout after top-kill (see also McCune 1988). At the opposite extreme were species, mainly oaks, with fire-sensitive shoots, but with a pronounced ability to resprout after top-kill. That resprouts were much taller than seedlings for each species reinforces the conclusion that post-fire resprouting is a viable strategy for persistence in these communities. The extent to which the negative correlation between fire resistance and resprouting represents a morphologically based tradeoff is unclear. Plant allocation to traits conferring stem resistance to fire (thick bark) may reduce allocation to root reserves required for prolific post-fire resprouting.

Results from the two unburned sites suggest that fire suppression, through its effects on litter depth and light, reduces pine, but perhaps not oak, establishment. Increasing canopy of silverleaf oak and total tree density increased litter depth and canopy cover, and these two variables decreased pine establishment. In contrast, juvenile cover of silverleaf oak actually increased with tree density, and silverleaf oak density was unaffected by litter depth and canopy cover. These results probably reflect the high proportion of silverleaf oak juvenile stems attributable to root sprouts: the number of oak sprouts is likely to increase with the number of mature trees. New techniques for distinguishing sprouts from seedlings or long-term monitoring of newly established seedlings would be required to assess the effects of fire suppression on silverleaf oak seedling establishment.

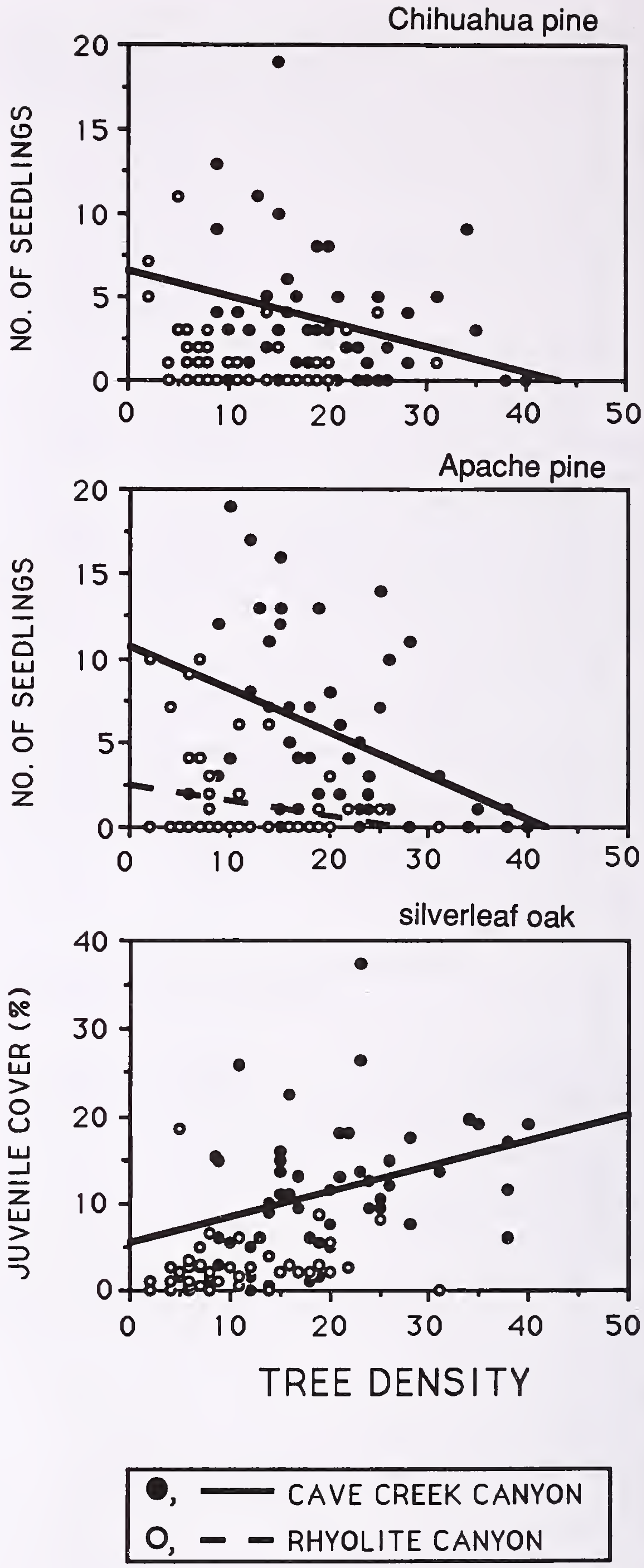


**Figure 2**—Abundance of juveniles of two pines and silverleaf oak in relation to density of trees (>1.4 m tall) in two sites. Data are number of seedlings for the pines and percent cover (<1.4 m height) for the oak in 5- by 10-m areas. Drawn regression lines are $p < .10$.

The increased biomass of silverleaf oak associated with fire suppression has probably resulted from this species' ability to resprout after fire and to subsequently fill in the canopy through both vertical and horizontal growth. In contrast, prolific resprouting, coppice growth, and horizontal spread is very limited in the fire-resistant pines. During presettlement times, fires probably maintained lower oak biomass, more favorable litter and light levels, and higher rates of pine establishment (see Marshall 1957). This scenario suggests that silverleaf oak biomass is likely to continue to increase at the expense of pines in these forests.

The contrast between fire resistance and post-fire resprouting strategies probably has important consequences for community composition over a wide range of fire frequencies and intensities, (for related examples, see Malanson and Westman 1985; Keeley 1991). Frequent, low-intensity fires, which probably characterized presettlement fire regimes, should favor the fire-resistant pines. In contrast, infrequent, high-intensity (especially stand-replacing) fires should favor resprouters such as silverleaf oak. Pines may even be largely eliminated by such fires, especially those sufficiently large to substantially reduce pine seed rain into burn interiors. This scenario suggests strongly the need for further research on the consequences of contrasts in fire adaptation for maintenance of heterogeneity and species diversity in natural and managed landscapes in Madrean and other ecosystems.

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# Vegetation Establishment on Rehabilitated Bulldozer Lines After the 1988 Red Bench Fire in Glacier National Park

**Nathan C. Benson**
**Laurie L. Kurth**

On September 6, 1988, in the North Fork valley of the Flathead National Forest, a smoldering patch of vegetation erupted into a fast-moving wildfire. In less than 24 hours it burned 6,000 acres, jumping the North Fork of the Flathead River and burning into Glacier National Park. The severe drought of 1988 combined with strong winds made the conditions right for a large stand-replacing fire. Immediately, the National Park Service and the Forest Service attempted to suppress the Red Bench Fire. Approximately 1,600 people, with the support of helicopters, airplanes, bulldozers, and feller-bunchers, fought the blaze. Eleven days later, wet and snowy weather extinguished it. The Red Bench Fire had burned 32,400 acres, 22,200 of them in the Park. This naturally ignited fire, because of its size and intensity, was the most ecologically significant fire to burn in the North Fork of the Flathead River drainage since 1926 (Wakimoto and Willard 1991).

Suppression efforts on the Red Bench Fire created 25.5 miles of firelines within Glacier National Park, 19.3 miles constructed with bulldozers and feller-bunchers and 6.2 miles made by fire crews using hand tools (Glacier National Park 1990). The firelines varied in width: the heavy equipment lines were 10 to 30 feet wide and the hand lines, 3 to 5 feet. All of the firelines were deep enough to reach mineral soil.

Immediately after precipitation extinguished the fire, Glacier National Park brought in heavy equipment and two crews, each consisting of over 20 people, to rehabilitate these firelines. The rehabilitation involved returning the removed material (duff, forbs, grasses, shrubs, soil, fallen trees, and tree branches) back to the firelines.

Fire has influenced the vegetation of the Rocky Mountain region more than any other natural disturbance. The influence of fire is readily apparent on Glacier National Park's vegetation. Stand age classes and vegetation types reflect the Park's fire regime (Habeck 1970; Barrett 1983). Fire encourages the growth of trees (lodgepole pine, Douglas-fir, ponderosa pine, and larch) that prefer or tolerate disturbance (Vale 1982). Particularly on the west side of the Park, fire has played an important role in establishing a diversity of landscapes and biotic communities (Kessell 1977).

In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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Lightning fires will always be a part of Glacier National Park. Park managers develop fire management practices that attempt to balance protection of people and adjacent land owners with the ecological needs of the natural resource. Suppression efforts generally result in disturbances that may have long-term unacceptable impacts to the natural resource. Because little information is available regarding these impacts, it is difficult to weigh them against impacts to humans. Frequently, the drama of a crown fire racing through the forest will prompt managers to use maximum suppression efforts.

## RESEARCH OBJECTIVES

We compared (in three different forest habitats) initial vegetation establishment and long-term succession along bulldozer lines, in adjacent burn areas, and in adjacent undisturbed forests. In addition, we documented the establishment of exotic species.

The first three years of data provided resource managers with preliminary information on early succession and the presence of exotic species within the bulldozer lines and the burned area.

## METHODS

Study sites were chosen to represent three of the major forest types in which firelines were created: 1) old growth Douglas-fir (*Pseudotsuga menziesii*); 2) dog-hair lodgepole pine (*Pinus contorta* v. *latifolia*); 3) Engelmann spruce (*Picea engelmannii*). At each study site 7- by 35-meter plots were randomly established along the bulldozer line, in the burn, and in the undisturbed forest (Table 1).

Data were collected at each site in late summer from 1989 to 1992. At each plot, ocular estimates of species' canopy cover and ground cover were made, and plot characteristics (aspect, slope, elevation) were recorded. Field procedures followed those of the Forest Service's Ecosystems Classification

**Table 1**—Number of plots within each plot type at each forest type.

| Plot type | Douglas-fir | Lodgepole pine | Engelmann spruce |
|---|---|---|---|
| Bulldozed | 12 | 12 | 16 |
| Burned | [1]0 | 3 | 4 |
| Undisturbed | 3 | 3 | 4 |
| Total | 15 | 18 | 24 |

[1]The fire did not burn near this bulldozer line.

**Table 2**—Number of species found at each plot type within each forest type.

| Forest type | Bulldozed | Undisturbed | Burned |
|---|---|---|---|
| Douglas-fir | 136 | 78 | [1]0 |
| Engelmann spruce | 131 | 101 | 102 |
| Lodgepole pine | 113 | 53 | 52 |
| Total | 178 | 124 | 113 |

[1] The fire did not burn near this bulldozer line.

Handbook (1987). Botanical nomenclature followed Hitchcock and Cronquist (1973) and Lesica (1985).

## RESULTS

One hundred and ninety-one species of vascular plants were found within the 57 study plots (Table 2). The bulldozed plots had the highest number of species, followed by the undisturbed plots, and then the burned plots. Perennial herbs on all of the plot types accounted for the majority of the species (Benson 1993).

Through the first three years of sampling, average species richness in the undisturbed plots remained relatively stable, while the bulldozed and burned plots displayed different trends. Both the bulldozed and burned plots showed strong increases in average species richness from the first to second year (Fig. 1). During the third year, the bulldozed plots' average species richness increased noticeably (Fig. 2). In comparison, the burned plots showed little change. The spruce forest plots showed a slight decrease in average species richness, and the lodgepole pine forest plots exhibited a slight increase (Benson 1993).

Of the 191 species identified, 38 species (20%) were found exclusively on the bulldozed plots, while only eight (4%) were restricted to undisturbed sites (Table 3). The burned and bulldozed plots had 15 species (8%) found on both sites but not found on the undisturbed sites. The undisturbed and burned sites had four species (2%) not present on any of the bulldozed plots. No species were unique to the burned sites (Benson 1993).

Twenty-three species, 13% in the bulldozed plots, were exotic plants, of which 15 were unique to the bulldozed plots (Table 4). In comparison, the burned plots had five exotics (4%) and the undisturbed plots had three exotics (2%). All of these exotics occurred on the bulldozed plots.

Fowl bluegrass (*Poa palustris*), the only dominant exotic species on any of the plots, was the dominant species on three wet bulldozed plots in the spruce forest; fowl bluegrass had a mean canopy cover of 30%. In an adjacent undisturbed plot, fowl bluegrass had a canopy cover of 10%; it was present in only one of the burned plots at a trace level.

In the study area, seven exotic herbs were found that are invasive and aggressive plants capable of displacing native species (Glacier National Park 1991). All seven were found on the bulldozed plots, three were found on the burned plots, and none were present in the undisturbed plots. Two of these exotics, oxeye-daisy (*Chrysanthemum leucanthemum*) and butter-and-eggs (*Linaria vulgaris*), occurred in only one bulldozed plot with a canopy cover of less than 1%. The other five exotic species occurred more than once. With the exception of Kentucky bluegrass (*Poa pratensis*), their canopy cover at each plot was always less than 5% and the majority of the time less than 1%.

## DISCUSSION

Vegetation establishment differs on the bulldozer lines and in the burned area. Early successional vegetation on the bulldozer line is more diverse than the burn's vegetation. Moreover, species were still establishing themselves on the bulldozer lines after the second year, and the three plot types differed in species composition.

Exotic species are present on the bulldozer lines in greater number than in the burn and undisturbed forest.

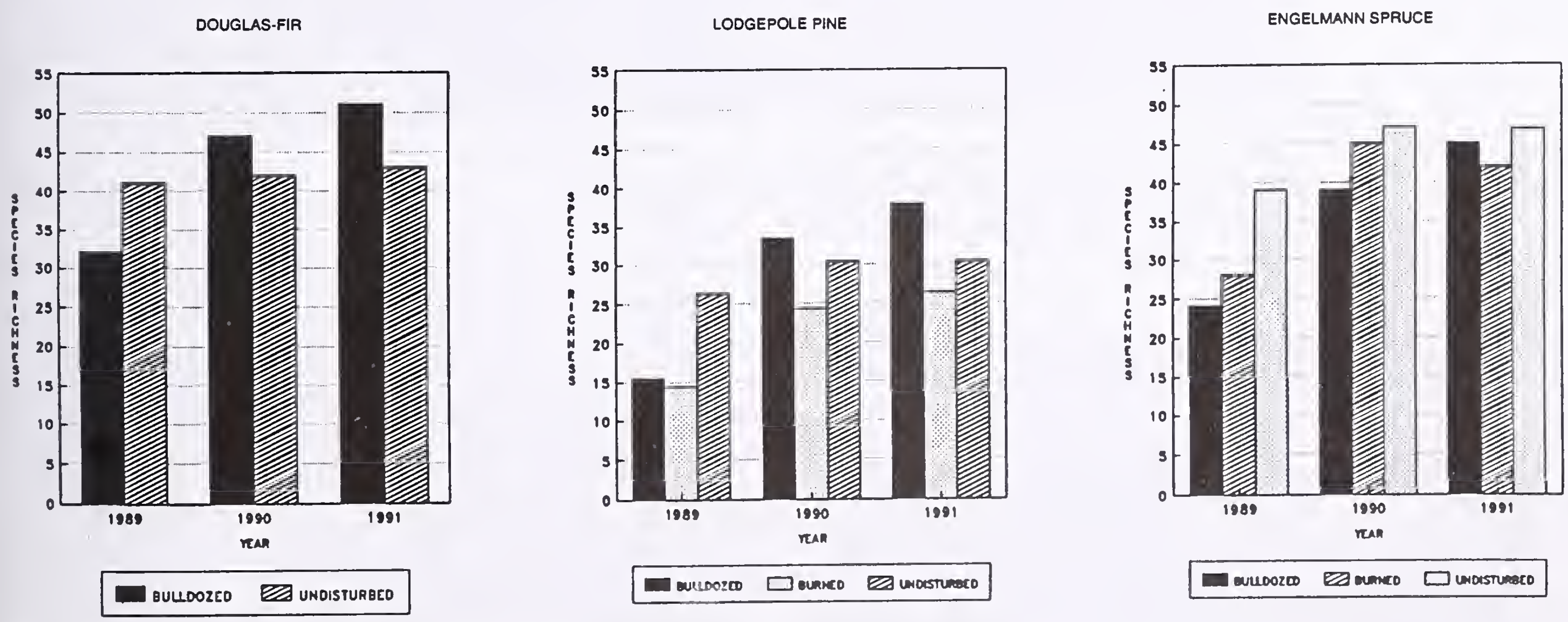


**Figure 1**—Average species richness of bulldozed, burned, and undisturbed plots located in the Douglas-fir forest, 1989 to 1991.

**Figure 2**—Photographs of a study plot on a bulldozer fireline in lodgepole pine forest, before (a) and after (b) rehabilitation. The upper picture was taken in October of 1988 and the lower in August of 1991.

**Table 3**—Number of species unique to the bulldozed, undisturbed, bulldozed and burned, and burned and undisturbed plots, 1989 through 1991.

| Plot types | Unique species | Percent[1] |
|---|---|---|
| Bulldozed | 38 | 20 |
| Undisturbed | 8 | 4 |
| Bulldozed & burned | 15 | 8 |
| Bulldozed & undisturbed | 4 | 2 |

[1]Percent of 191 species.

Most of the exotics occur infrequently and with a canopy cover of less than 5%. Seven of these exotics are aggressive and invasive. Fowl bluegrass is the only dominant exotic at any of the plots. Further monitoring of the bulldozer lines will allow the Park's resource managers to gauge the long-term impact of these exotic species.

Vegetation change is a dynamic process that does not necessarily lead to predictable outcomes. Often small environmental changes will result in long-lasting alteration of vegetation (Sprugel 1991). Bulldozer disturbance could potentially produce a persistent community that differs

Table 4—Exotic species present in bulldozed, burned, and undisturbed plots, 1989 to 1991.

| Species | Bulldozed Freq.[1] | Bulldozed Cover[2] | Burned Freq. | Burned Cover | Undisturbed Freq. | Undisturbed Cover |
|---|---|---|---|---|---|---|
| *Agrostis alba** | 18 | 2 | 5 | t[3] | — | — |
| *Chrysanthemum leucanthemum** | t | t | — | — | — | — |
| *Cirsium arvense** | 33 | t | 5 | t | — | — |
| *Cirsium vulgare** | 58 | 2 | 38 | 2 | — | — |
| *Filago arvense* | t | t | — | — | — | — |
| *Linaria vulgaris** | t | t | — | — | — | — |
| *Matricariama tricarioides* | 2 | t | — | — | — | — |
| *Panicum capillare* | 6 | t | — | — | 10 | 4 |
| *Phleum pratense** | 19 | 2 | — | — | — | — |
| *Plantago lanceolata* | 2 | 3 | — | — | — | — |
| *Plantago major* | 7 | t | — | — | — | — |
| *Poa palustris* | 16 | 9 | 5 | t | 10 | 3 |
| *Poa pratensis** | 5 | 3 | — | — | — | — |
| *Polygonum aviculare* | t | t | — | — | — | — |
| *Silene cucubalis* | 2 | t | — | — | — | — |
| *Taraxacum officinale* | 52 | 2 | 2 | 43 | t | 27 |
| *Trifolium agrarium* | 4 | t | — | — | — | — |
| *Trifolium hybridum* | 8 | 2 | — | — | — | — |
| *Trifolium pratense* | 3 | 2 | — | — | — | — |
| *Trifolium procumbens* | 2 | 4 | — | — | — | — |
| *Trifolium repens* | t | t | — | — | — | — |
| *Verbascum thapsus* | t | 3 | — | — | — | — |
| *Veronica serpyllifolia* v. *humifusa* | 2 | 3 | — | — | — | — |

[1]Frequency is the percent of the 120 bulldozed plots in which the species was found.
[2]Cover is the mean percent canopy cover of the species.
[3]t is less than one percent.
*Invasive and aggressive.

from both the burned and undisturbed communities. Glacier National Park will continue to monitor the bulldozer lines in order to assess whether the vegetation corresponds to the natural range of vegetation of the area or to a new equilibria, which would compromise the wilderness of the Park (Vale 1982; Sprugel 1991).

## ACKNOWLEDGMENTS

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# Postfire Regeneration and Clonal Growth Strategies of Two Florida Scrub Oaks

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**Eric S. Menges**

Relatively small, isolated fragments of scrubby-flatwoods and sandhill survive undeveloped on central Florida's sand ridges. Scrubby-flatwoods is a shrub community dominated by the xeromorphic sand live oak (*Quercus geminata* Small) and the endemic, scrub oak (*Q. inopina* Ashe). A total of 17 plants, 40 arthropods, and 5 vertebrates are endemic to this pyrogenic, endangered community. So that species with special habitat requirements will not be adversely affected and perhaps be eliminated, the management objective for scrub preserves maintains various stages of developmental structure (Myers 1990). Where fire suppression has been successful for 65 years, scrub oak abundance declines, while sand live oak increases (Givens and others 1984 and Menges and others 1993). A mean fire return interval of about 10 to 20 years is proposed to maintain open scrub habitat and associated endemic species (Ostertag and Menges 1994). Little is known, however, about either the fire ecology or habitat requirements of scrub plants.

Sandhill is a high pine community containing an overstory of thick-barked pines and an understory of herbs and grasses, which is maintained by a frequent, low-intensity fire regime (Myers 1990). Where fire suppression has been successful, scrub oaks, most notably sand live oak, have invaded (Myers 1985 and Menges and others 1993). To successfully restore sandhill communities, managers are attempting to remove sand live oak using prescribed fire.

We are conducting studies of the clonal growth, resource allocation, and post-fire regeneration strategies of sand live oak and scrub oak in order to understand and predict the effects of different fire regimes on these key species.

Our studies suggest that sand live oak's clonal growth strategy is better adapted to a fire regime having long fire-free, low-light periods than scrub oak's. Sand live oak clones excavated from long-unburned areas consisted of one large, thick-barked, old stem and many smaller stems connected to the central stem by a few long, thin, radiating rhizomes. Scrub oak clones, on the other hand, had small, short-lived stems with high stem turnover rates. Its rhizomes were shorter, thicker, and older than sand live oak's. Scrub oak's rate of clonal advance was less than one-sixth that of sand live oak. Sand live oak's superior ability to maintain itself in the canopy, gathering light while its rhizomes efficiently forage for scattered patches of light, may enable it to outcompete scrub oak in the low-light environment of many long-unburned scrub sites. A few large sand live oak stems were also able to survive and crown-sprout following a low-intensity scrub fire to which all of the surveyed scrub oaks succumbed.

When top-killed by fire, both species responded similarly. They resprouted rapidly during their first two growing seasons, while subsequent growth was considerably reduced. New volumes of rhizomes produced by each immediately following fire were not significantly different. Pre-fire, an average of over 60% of both plants' total biomass was below-ground, suggesting considerable allocation to a combination of storage, soil resource acquisition, and vegetative reproduction. We are currently testing our hypotheses that their post-fire stem growth dynamics are linked to changes in below-ground carbohydrate storage, changes in post-fire nutrient availability, and shifts in allocation to clonal expansion. These studies are enabling us to determine when these species are most vulnerable to fire, ensuring that prescribed fire programs will maintain them in scrubby-flatwoods communities and successfully remove them from the sandhills which they have invaded during a period of fire suppression.

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# Spatial Changes in Forest Landscape Patterns from Altered Disturbance Regimes on the Eastern Slope of the Washington Cascades

**Ann Camp**
**Chad Oliver**
**Paul Hessburg**
**Richard Everett**

Disturbances are an intrinsic part of ecosystem development (Cooper 1913; Watt 1947; Oliver 1981). Disturbance events and stand dynamics interact, giving pattern to vegetation across landscapes (Pickett and White 1985; Krummel and others 1987; Oliver and Larson 1990). Pre-European settlement fire regimes on the eastern slopes of the Cascade Mountains in Washington created and maintained a shifting mosaic of forest stands. Many Douglas-fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*) climax forests were subject to low- or moderate-severity fire regimes. High-severity fire regimes were characteristic of some north slope and many higher elevation forest types (Agee 1990). Periodic underburning (low-intensity fires) separated ground and canopy fuels and maintained lightly stocked, single-layered stands. Moderate-severity fires left varying amounts of live trees and enhanced structural and biological diversity within and between stands. High- and low-severity fires initially homogenized areas; then, unique characteristics and site potential were manifested and patches emerged within patches. At the landscape scale (10-100,000 acres) the vegetation pattern was heterogeneous.

Landscape vegetation patterns are important from both disturbance propagation and wildlife habitat perspectives. Spread of disturbances across landscapes is a function of the spatial heterogeneity of vegetation (Romme 1982). Landscape vegetation configurations can enhance (Turner and Bratton 1987; Franklin and Forman 1987) or retard (Knight 1987) the spread of such disturbances as stand-replacing fires or disease and insect outbreaks. The landscape pattern of vegetation is important to wildlife species, with different species requiring specific stand structures and landscape configurations. Northern spotted owls (*Strix occidentalis caurina*) require some stands having late-successional characteristics (Forsman 1980). Rocky Mountain elk (*Cervus canadensis*) need habitat elements from both regenerating and maturing stands. Landscape habitat patterns determine species feeding, breeding, and migration successes.

Disturbance effects vary with topography, soils, and vegetation (Swanson and others 1988). Fire effects further vary with amount, type, and distribution of fuels, timing of ignition, and atmospheric and climate conditions. Some areas are virtually unaffected by fire disturbances because of their location within landscapes or particular environmental conditions. Other areas escape one or more disturbance events because of vegetation characteristics related to stand development histories (Oliver and Larson 1990). Under historical fire regimes, some stands burned less often than others. These stands achieved late successional composition and structures in landscapes dominated by younger forests. Late-successional stands embedded in a matrix of early and mid-successional stands may be thought of as "refugia." Likewise, early-successional stands in a matrix of late-successional stands may also be thought of as refugia. Refugia may contain species that would be missing if subjected to the characteristic disturbance regime of the surrounding vegetation matrix. Late-successional refugia in eastern Washington contain structures (snags, mistletoe brooms, fallen logs, multiple canopy strata) that provide habitat elements for some wildlife species (Forsman and others 1990).

Natural stand development patterns following decades of fire suppression and economically influenced partial cutting allowed shade-tolerant and fire-intolerant species to establish and grow in the understory. Stand density increased, stands became multi-layered, and landscape vegetation patterns became more homogeneous (Lehmkuhl and others 1993). Late-successional and climax refugia, historically embedded in a matrix of early- and mid-successional stands, are coalescing to form a new matrix. Landscapes are becoming more homogeneous, as early- and mid-successional stands are replaced by later-successional, multi-layered forests (Lehmkuhl and others 1993). Competition for limited site resources in these dense stands creates stresses that increase the risk of insect outbreaks, root diseases, dwarf mistletoe epidemics, and stand-replacing fires (Agee 1993). Absence of recent fires in Douglas-fir and grand fir climax forests has perhaps been the single

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greatest management influence on landscape diversity of eastside forests (Agee 1993; Lehmkuhl and others 1993).

## OBJECTIVES

National Forests in eastern Washington and the Forestry Sciences Laboratory in Wenatchee, Washington, are conducting a study to determine historical and recent changes in forest vegetation patterns. Specifically, changes in the extent, pattern, and structure of late-successional and climax stands within these forests will be quantified. The objectives of this study are to:

- determine the pattern (location, size, composition, structure, and spatial relationships) of late-successional and climax stands (refugia) on pre-settlement and current landscapes;
- determine vegetation pattern across the landscape during the past 200 to 400 years; and,
- determine how the range and variability of fire return intervals affects vegetation pattern at stand and landscape levels.

## METHODS

The study area is the 175-square mile Swauk Northern Spotted Owl Habitat Conservation Area (HCA) on the Wenatchee National Forest. This area is comprised predominantly of Douglas-fir, grand fir, and subalpine fir (*Abies lasiocarpa*) climax plant associations (Franklin and Dyrness 1973; Williams and Smith 1991).

The study area was partitioned into 21 drainages. These were further subdivided into next-order sub-drainages, which were randomly selected for extensive sampling. Within each sampling unit, line transects were established perpendicular to the slope. Intervals between transects were 0.1 mile. At 0.1-mile intervals along each transect, we established plots and collected data, including aspect, elevation, slope, percent crown closure, number of canopy layers, and stand history. At least six trees within a 50-foot radius were cored to determine age classes and fire histories. Multivariate regression and classification and regression tree analysis (CART) (Breiman and others 1984) will be used to relate fire return intervals (derived from age classes, growth patterns, and fire scars) with combinations of physiographic variables and vegetation attributes.

In 1993, sampling will continue in selected sub-drainages. Stand development patterns will be reconstructed within refugia that pre-date the onset of fire suppression. Fire histories will be determined from stumps within stands that have been logged during the past ten years, from wedges collected during sampling, and from wedges collected during previous studies within the HCA (Schellhaas and others, unpublished data).

Field-verified vegetation pattern and its aerial photographic signature will be compared with and correlated to recent and historical photo-interpreted data. These comparisons will allow us to determine probable stand development patterns over a much larger area than could be sampled directly.

## PRODUCTS

A predictive model relating late successional and climax stands (refugia) pre-dating European settlement to a suite of measurable physiographic variables and vegetation attributes will be developed. A GIS-based model showing decadal changes in landscape patterns over the past century, and as far back as data allow, will also be developed.

## PRELIMINARY FINDINGS

The histograms in figures 1 to 4 are from data collected during the summer of 1992. The sub-drainage age class histogram (fig. 1) was derived using data from 29 plots. Age classes are decadal and consist of trees (aged at d.b.h.) from the previous nine years; for example, age class 20 includes trees between 11 and 20 years. In a few cases butt rot precluded exact aging. Analysis of core length and growth patterns of rotten and proximate healthy trees allowed estimation of probable ages of rotten trees. Initial data analysis suggests three stand profiles:

- stands that almost never develop beyond early and mid-seral stages (fig. 2a,b);
- stands that experience fires infrequently and develop into late-successional or climax stages that may persist for centuries (fig. 3a,b,c); and,
- stands that temporarily achieve late-successional status (fig. 4a,b).

The latter two categories would generate spatially and temporally shifting patterns of late-successional refugia over the landscape.

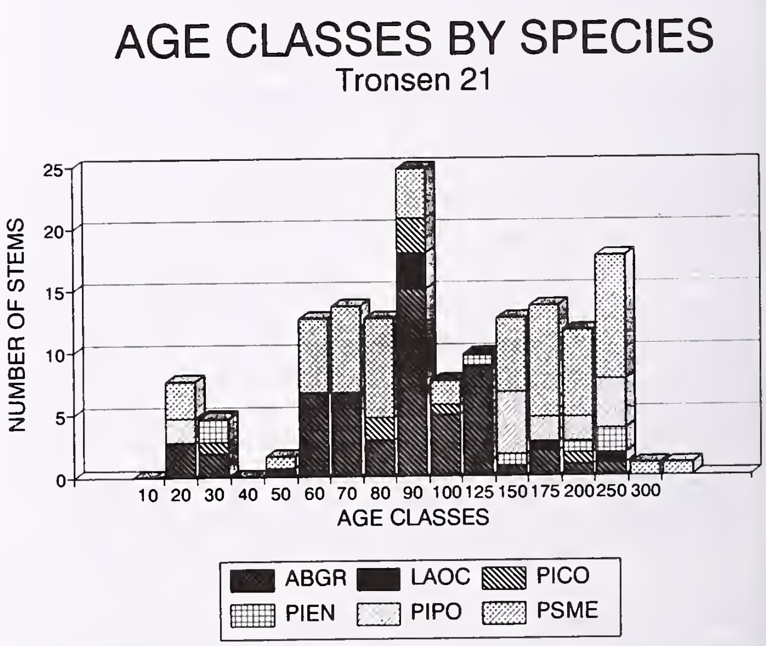


**Figure 1**—This sub-drainage age class histogram was derived using data from 29 plots. Age classes are decadal, consisting of trees from the previous 9 years. Species codes are: ABGR. grand fir; LAOC, western larch; PICO, lodgepole pine; PIEN, Engelmann fir; PIPO, ponderosa pine, and PSME, Douglas-fir.

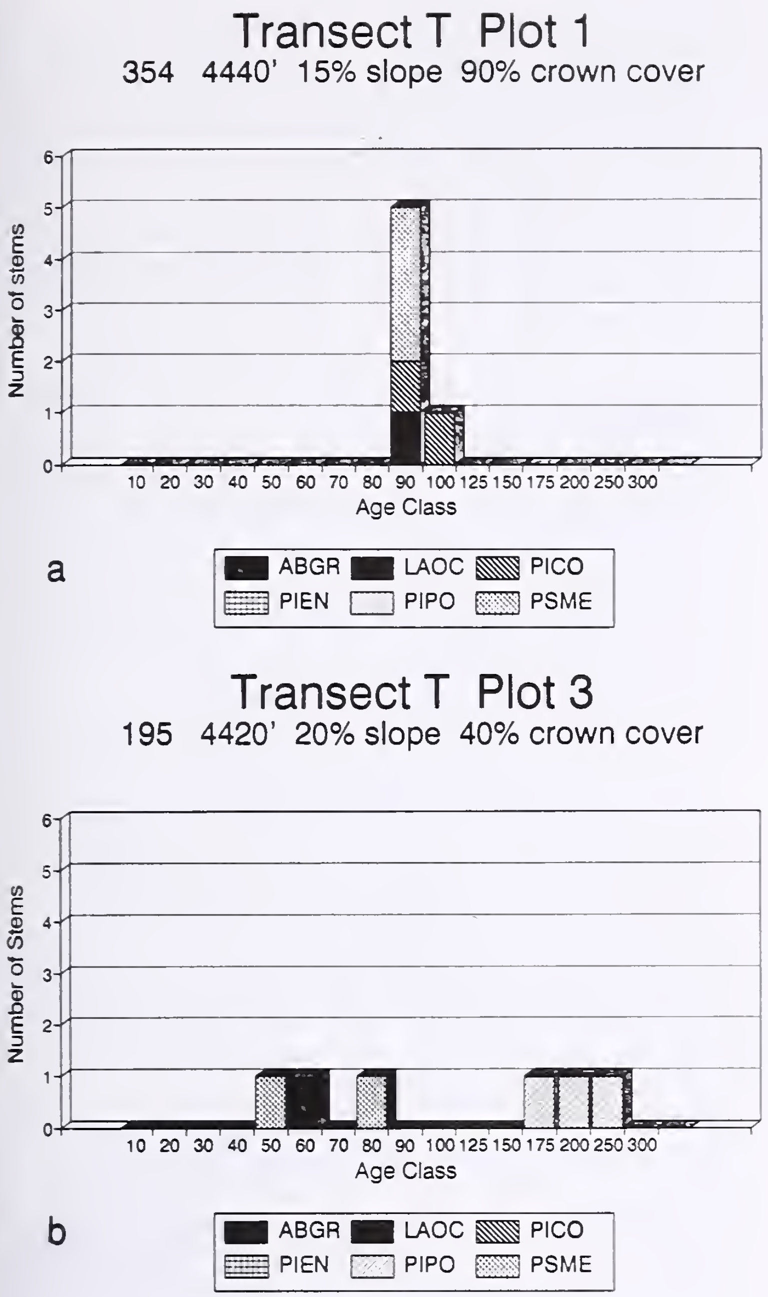


**Figure 2**—Some stands lmost never develop beyond early and mid-successional stages. See figure 1 for species codes.

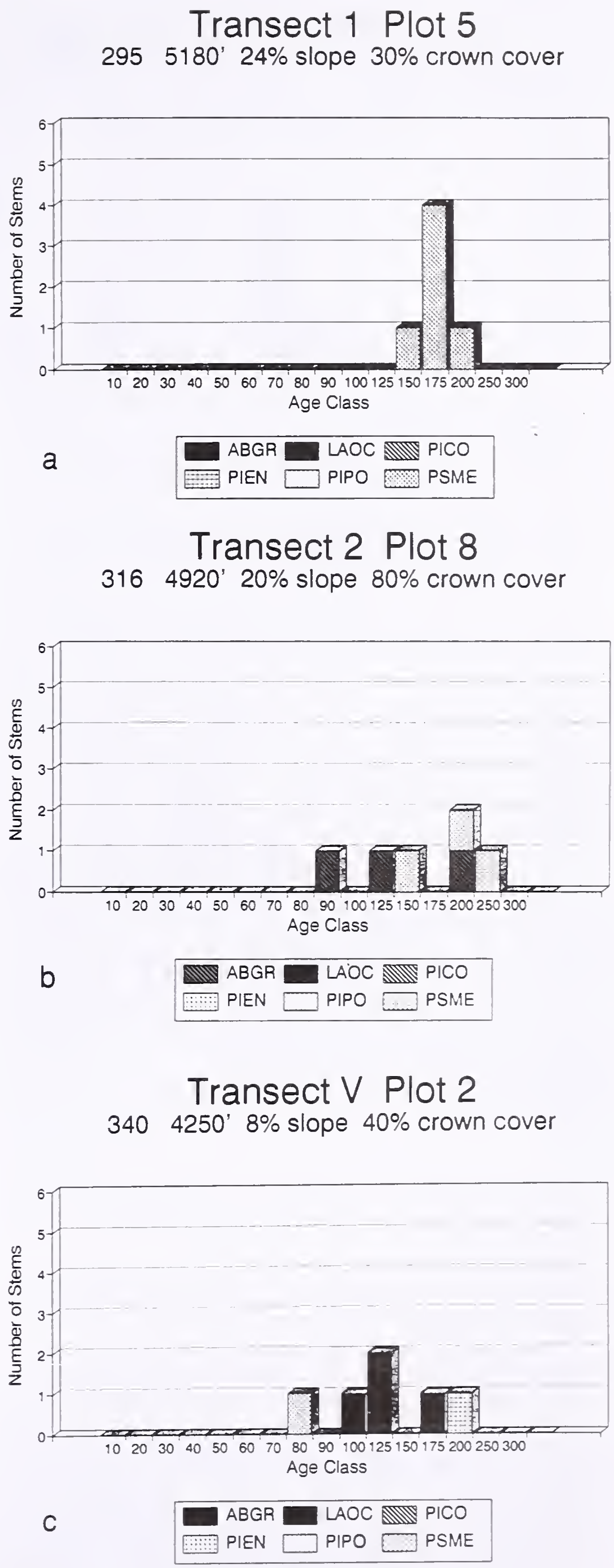


**Figure 3**—Some stands experience fires infrequently and develop into late-successional or climax stages that may persist for centuries. See figure 1 for species codes.

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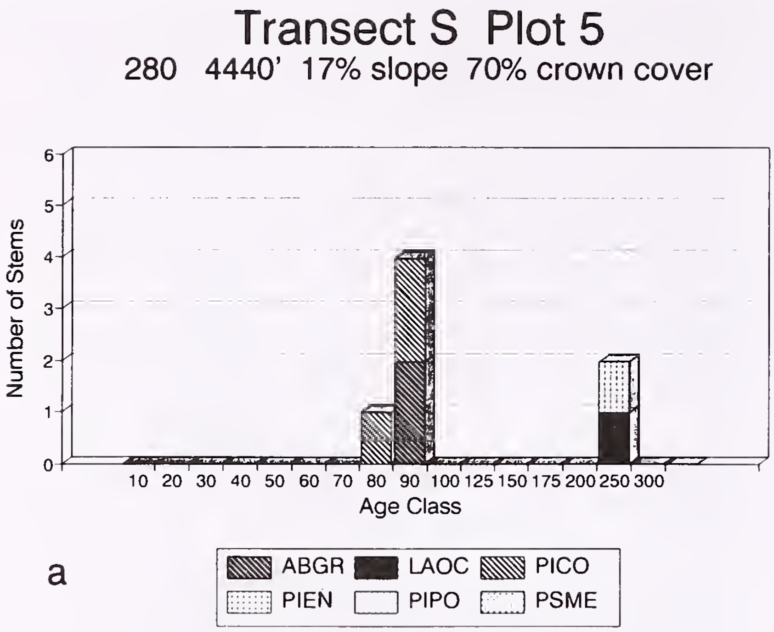


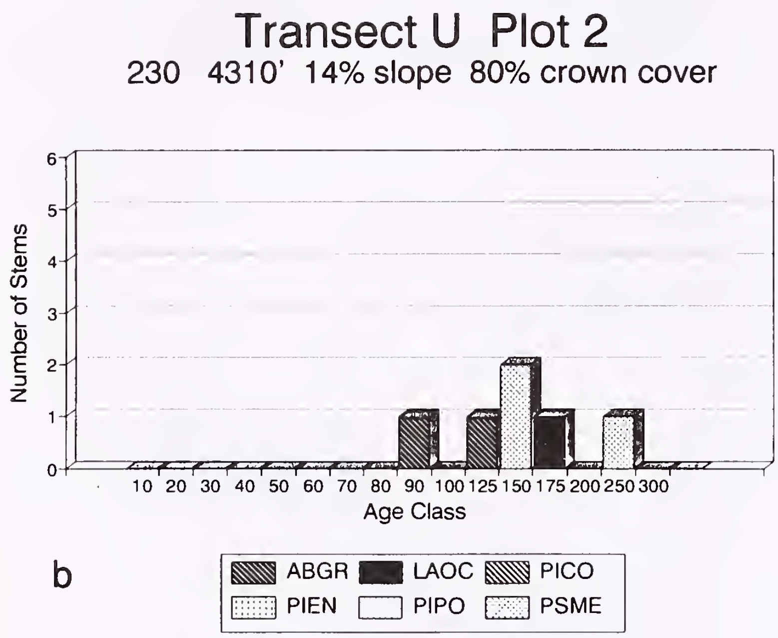


**Figure 4**—Some stands temporarily achieve late-successional status. See figure 1 for species codes.


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# Historic Fire Regimes Along an Elevational Gradient on the West Slope of the Sierra Nevada, California

**Anthony C. Caprio**
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The vegetation of Sequoia National Park, and the Sierra Nevada in general, has been greatly altered since the arrival of large numbers of Europeans in the nineteenth century. This change was largely due to the modification of the historic fire regimes (Kilgore and Sandro 1975; Vankat and Major 1978). The "natural" fire regime in the past was one of low-severity surface fires with crown fires uncommon (Show and Kotok 1924; Kilgore 1973). As elsewhere in the Western United States, suppression of pre-European fire regimes resulted in shifts in successional patterns and, in some cases, produced undesirable changes in vegetation composition and structure. The modification of historic fire patterns was due to a variety of land use practices and fire suppression efforts (Biswell 1959; Vankat 1977; Shaman and Warren 1988). Because no documentary records of fire regimes exist prior to European settlement, "proxy" data must be sought to provide this information. One type of proxy data exists as fire scars on trees that survived but were injured by past fires. These injuries are usually visible as open scars or "cat-faces" at the base of a tree and may contain multiple fire-caused lesions (Lachmund 1921; Dieterich and Swetnam 1984).

Fire scars have been widely used in determining occurrence of past fires in the western United States (Clements 1910; Keen 1937; Houston 1973; Arno and Sneck 1977; Swetnam and Dieterich 1985; and many others). Previous fire history studies in the ponderosa pine and Jeffrey pine forests (yellow pine forests) in southern California relied on ring-counting methods for dating fire scars (Show and Kotok 1924; Wagener 1961; Kilgore and Taylor 1979; Warner 1980; McBride and Jacobs 1980; Pitcher 1987). Although for some purposes this method provides adequate estimates of fire frequency, for other purposes the resulting approximate fire dates lack the necessary level of precision. In contrast to ring counting, dendrochronologically crossdated fire histories are accurate to the year because each annual ring is precisely dated to the year of formation. Thus, there is accurate placement of each fire event in space and time, which is particularly important for forest ecosystems with high fire frequency (less than 5 years) (Madany and others 1982). This allows precise comparisons of fire dates within and among sites and regions, providing a sound basis for inferring fire spread, size, and extent patterns. Additionally, because fire dates are accurate to the year, they can be compared to seasonal or annual climatic data, leading to better understanding of fire climatology (Baisan and Swetnam 1990). Finally, use of cross-dating techniques permits the utilization of remnant logs and snags, greatly reducing the number of samples that need to be removed from living trees. This is an important consideration when sampling must be conducted in parks or wilderness areas.

The goal of this study was to document fire occurrence patterns in montane forest stands on the west slope of the Sierra Nevada for the last 300 to 400 years using dendrochronological analysis of tree-ring samples. We investigated historic fire regimes by collecting fire-scarred specimens from logs, snags, or living trees in Sequoia National Park along an elevational gradient. Our interpretation of this fire-history record provides a historical perspective on the past fire regime in this area, including estimates of fire frequency, spatial extent and spread patterns, fire synchrony among sites, and seasonality of fires. This fire history was also compared to fire chronologies constructed from dead giant sequoias (*Sequoiadendron giganteum*) obtained in the Giant Forest (Swetman et al. 1992). These data provide resource managers and researchers detailed information on fire occurrence and variability across a range of temporal and spatial scales. Such information is important for improving our understanding of current and past vegetation composition and processes in parks and wilderness areas. This was the first of several fire-history transects that we plan to develop on the west slope of the Sierras. Additional sampling is also underway to extend this transect to higher elevation sites. Our ultimate goal is to develop a network of fire history sites and transects that will be useful in the study of climate-fire interactions in the central and southern Sierra Nevada over the past several hundred years. This work is part of a larger research effort, funded by the National Park Service Global Change Program, to understand and predict climate-related changes in ecosystems of the Sierra Nevada (Stephenson and Parsons 1993).

## STUDY AREA

The transect was located in the Kaweah River watershed on the west slope of the Sierra Nevada in Sequoia National Park (Fig. 1). Collections were made at 15 sites

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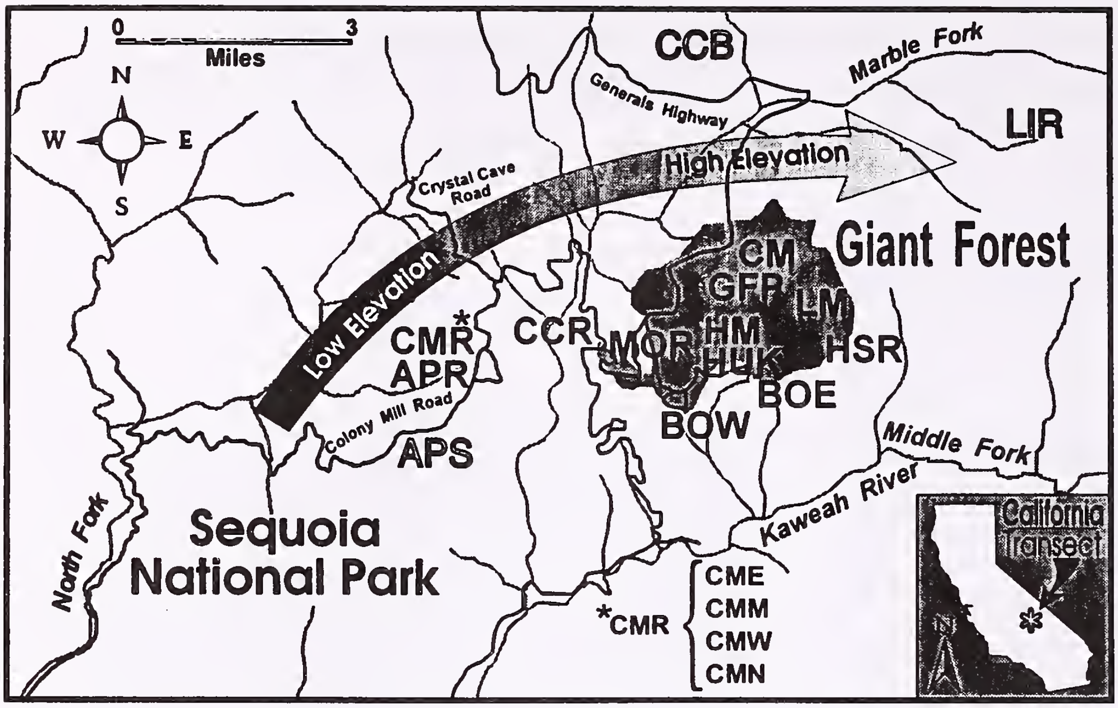


**Figure 1**—Study area on the west slope of the Sierra Nevada in Sequoia National Park. Location of the Giant Forest is shown by the shading. The west-to-east elevational increase along the transect is indicated by the large arrow. The map shows the locations of the 15 pine sites sampled (three-letter codes) with the 12 used in this analysis shown with solid letters. The eight giant sequoia sites sampled in three larger areas have these three areas shown by the two-letter codes. See text for explanation of the site abbreviations.

along the transect. Data from 12 of these sites are reported here. The area encompassed by each site ranged from about 0.25 to 2 ha. No obvious fire spread barriers were present within-sites. In general, the sites were selected so as to reduce possible effects of the size of area sampled or within-site variations on fire frequency estimates (Arno and Peterson 1983). Within-site characteristics were generally homogeneous with respect to current vegetation, topography, and aspect. All sites were located on the south-facing slope of the ridge forming the north flank of the Middle Fork of the Kaweah River. Elevations along the transect ranged from 1,550 to 2,200 m and extended from the upper edge of chaparral, black oak, and grassland communities into mid-elevation mixed conifer forest. There was a west-to-east elevation increase along the transect, although the transect was bisected by the Marble Fork of the Kaweah River.

Lower elevation sites were located along the Old Colony Mill Road near Ash Peak Ridge (APR) and on the ridge at the head of Cedar Creek (CMW, CMN, CMM, CME). Dominant tree overstory at these five lower sites was ponderosa pine (*Pinus ponderosa*) and California black oak (*Quercus kelloggii*) in moderately open stands. The Crystal Cave Road site (CCR) was located along a dry ridge midway between the Marble Fork bridge and the Generals Highway. The Moro Rock site (MOR) was located on the crest of the slope forming the west margin of Giant Forest. The overstory of these two sites was dominated by ponderosa pine and incense-cedar (*Callocedrus decurrens*) in moderately open stands. The Bobcat Point sites were situated on the upper portions of a slope, near Bobcat Point, south of Giant Forest. Bobcat East (BOE) was located on the east side of Crescent Creek and consisted of a very open stand of ponderosa pines. Bobcat West (BOW) was located on the west side of Crescent Creek in a relatively closed-canopy stand dominated by ponderosa pine, sugar pine (*P. lambertiana*), and white fir (*Abies concolor*). The Huckleberry site (HUK) was located on the south margin of Giant Forest with dominant canopy tree species similar to Bobcat West. Giant Forest Pine (GFP) was situated within the interior of the sequoia grove with a moderately open canopy dominated by ponderosa pine, sugar pine, white fir, and red fir (*Abies magnifica*). The High Sierra Ridge site (HSR) was located on a ridge forming the southeast boundary of the grove with a canopy dominated by ponderosa pine, sugar pine, and white fir. Previously developed giant sequoia fire histories at eight sites from three larger areas are located in Giant Forest. Species sampled along the transect were predominantly ponderosa pine and sugar pine, but also included Jeffrey pine (*P. jeffreyi*), incense-cedar, and California black oak.

## METHODS

Fire scar collections were made from multiple trees at each site since we seldom find any single tree that has recorded all fires that burned in the vicinity. Sample size varied from four to fourteen fire-scarred trees per site with a total of 91 trees sampled. This included the collection of 76 samples from logs and snags (at low-elevation sites we sampled many recently dead trees which appeared to have died as a result of the 1980's drought). Samples were removed from 15 living trees as partial sections (Arno and Sneck 1977), for the purpose of crossdating the remnant material and documenting the location and timing of recent fires.

Samples were surfaced and crossdated using standard dendrochronological techniques (Glock 1937; Stokes and Smiley 1968). Fire scars were assigned to the year of occurrence, and where possible, to a position within the annual ring. Intra-annual position of fire scars can provide an estimate of the season of past fire occurrence (Ahlstrand 1980; Barrett 1981; Dieterich and Swetnam 1984). Intra-annual positions of scars were recorded as "early in the earlywood", "middle of the earlywood", "late in the earlywood", "latewood", or "dormant" for the period when

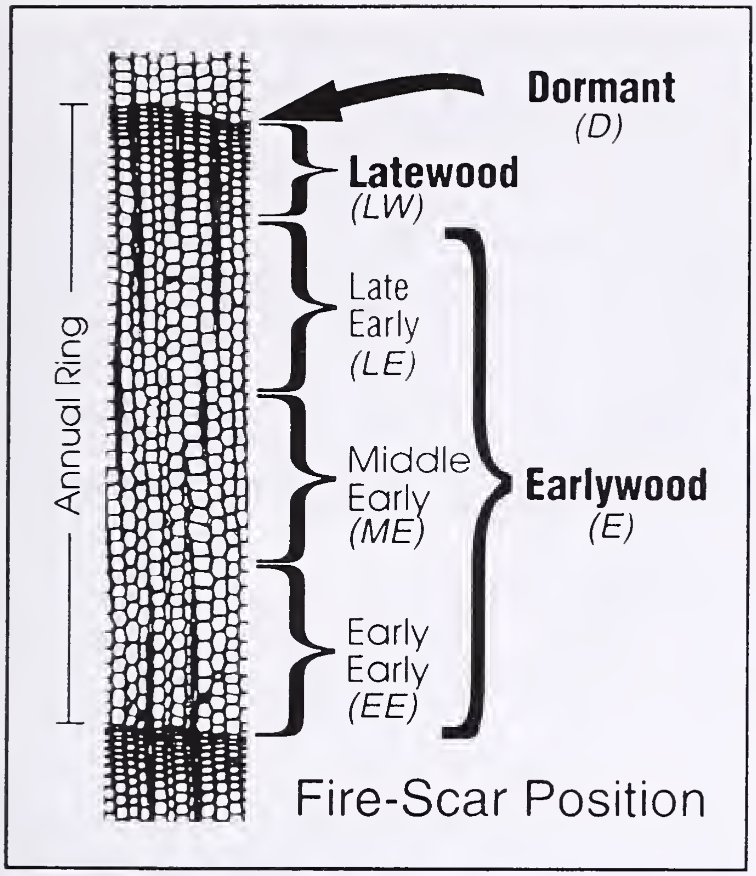


**Figure 2**—Areas of an annual ring used in designating intra-annual fire-scar positions.

cambial growth has become inactive (Fig. 2). Dormant season scars in the Sierra Nevada region were interpreted to have occurred in the calendar year corresponding to the adjacent latewood cells. This convention was established after observing that dormant season scars were always associated with late season scars (latewood) in nearby trees. In other words, in this region we interpret dormant season scars to represent fires occurring in late summer or fall after cambial cell division has ceased. This convention was also supported by our knowledge of the modern seasons of peak burning in this region (Show and Kotok 1923; Parsons 1981; NPS fire records for Sequoia National Park).

# RESULTS AND DISCUSSION

## Spatial Patterns

Master fire chronologies were developed for each sampled stand. Fire scar dates spanned the period from 1402 to 1988. From these chronologies a composite inter-site fire chronology was constructed which summarized the fire-history dates from all sites along the transect for the period extending back to the year 1600 (Fig. 3). Prior to about 1700 our sample depth (number of sampled trees) declined at most sites and past fire history and frequency estimates became less reliable. Widespread fire events (peaks in the fire-scar index with fires occurring over a broad range of elevations) were recorded in 1729, 1755, 1770, 1795, 1812, 1856, and 1873. Other less widespread events occurred in 1707, 1736, 1747, 1765, 1767, 1777, 1780, 1782, 1785, 1806, 1820, 1829, 1830, and 1851. The last widespread fire we recorded was in 1898. This last date and the location of the scarred trees correspond to a documentary record of a 8,098 ha-(20,000 acre) burn along the North and Marble forks of the Kaweah River in 1898 (Barrett 1935). Fire scars from twentieth-century wildfires were dated to 1910, 1947, and 1988 and prescribed burns to 1969 and 1971. These dates were recorded by National Park Service fire records or Superintendent's reports.

The coinciding dates of many fire events over much of the transect indicate that during the pre-settlement era many fires burned across the elevational gradient through a variety of habitats and vegetation types. The coherent and widespread fire events we detected for the pre-settlement period contrasts with the findings of Kilgore and Taylor (1979) who felt that fires were small and patchy for this period in the Redwood Mountain area of Kings Canyon National Park. The greater coherency in our

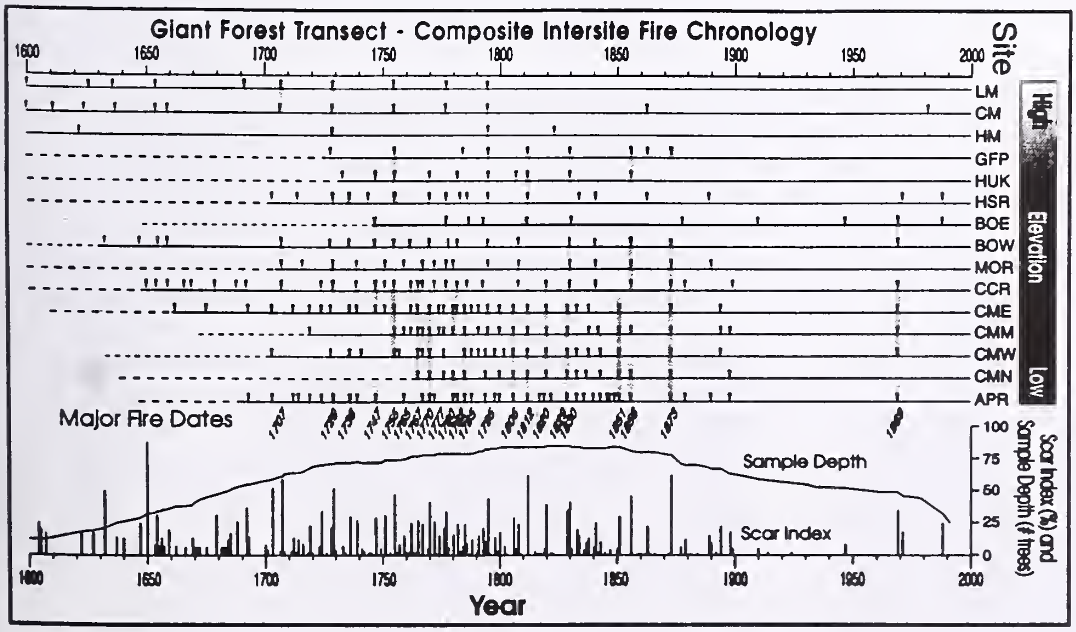


**Figure 3**—Composite intersite fire chronology for the Giant Forest transect. Each horizontal line is a composite fire record of all trees at a site. Only fire-scars found on two or more trees at a site are shown (solid triangles). The three upper horizontal lines show the fire-scar record from giant sequoias in three areas of the Giant Forest. Vertical shaded lines highlight synchronous fire events that occurred at five or more sites (major fire dates). Lower graph gives scar index-values (bars) for all fire scars recorded at all sites and the change in sample depth through time (curve). See text for explanation of the site abbreviations.

findings may be a consequence of our use of crossdating techniques which resulted in the determination of precise fire dates. The patterns we found suggest interconnections among the different vegetation types along the elevational gradient through the linkage of fire. Changes in the fire regime and associated vegetation patterns in one elevation zone could have important effects on fire regimes and vegetation patterns in other zones through a shift in fire spread patterns. For example, the alteration of mixed conifer forests may not entirely be a result of fire suppression in these forests but may partially be a result of settlement and development in lower elevation zones which prohibited fire spread in these areas. Thus historic fire regimes and events should not be perceived as solely a feature of a specific vegetation type but should be viewed in the context of a variety of vegetation types over a landscape through which fire may spread.

Comparison of fire dates from sites located within Giant Forest (GFP, LM, CM, HM) showed that nearly all of these fires were recorded by sites outside the sequoia grove; however, many fires recorded outside the grove were not recorded within the grove. This finding suggests that many fires recorded in the grove originated outside the grove, but not all fires burning up to the grove boundary successfully burned into the grove.

An inverse relationship was found between elevation and fire frequency for the 12 non-sequoia and eight Giant Forest sequoia sites (Table 1). The pattern of fire occurrence we observed does not necessarily imply that fire ignitions in the past were more frequent at lower elevations. This pattern was also inverse to the incidence of lightning ignitions recorded since 1921. On the west slope of the Sierras in Sequoia National Park most lightning ignitions occurred at higher elevation ridge tops, at about 2,500 m (Vankat 1985). This discrepancy might be explained, even with a reduced ignition rate at lower elevations, if fires typically were larger in these areas resulting in an overall higher fire frequency at any one location through time. We hypothesize that understory vegetation at these elevations consisted of a high proportion of flammable surface fuels (graminoids, for instance) with quick recovery rates following fires. This would enable fire to spread rapidly over large areas and to recur frequently. Although fires of large size might originate at any elevation, we would expect the probability of an ignition becoming a large fire at lower elevations to be greater than at higher elevations. A similar interpretation was expressed by Parsons (1981) based on a study of fire records for Sequoia and Kings Canyon National Parks: "When ignited under the proper conditions, few ignitions are needed to burn large areas of highly flammable chaparral and oak woodland."

Additionally, as a result of their size and the fuels they were burning in, many of these low-elevation fires could subsequently spread into higher areas. If this interpretation is correct, then lower-elevation vegetation types were an important dynamic linkage between different elevation zones through fire spread patterns.

## Temporal Patterns

Intervals between fires at particular sites ranged from 1 to 36 years. We observed changes in fire frequency in individual master fire chronologies and the composite inter-site transect chronology (Fig. 3). This is also apparent from a comparison of the fire interval frequency distributions for the 1700's and 1800's at three representative sites along the transect (Fig. 4). Fire frequency was high during the 1700's and began to decrease around 1800. It increased again at some lower elevation sites from about 1830 to 1850. Fire frequencies generally declined at all sites after this time. The decrease was most apparent and began earlier at the higher elevation sites than at the lower elevation sites (Fig. 3). The cause of the early fire frequency decline (about 1800-1830) was unknown, while the more obvious decrease in fire frequency at the end of the nineteenth century was probably due to grazing and subsequent fire suppression policies (Vankat and Major 1978; Kilgore and Taylor 1979). A similar historical pattern of increased domestic livestock grazing associated with decreases in fire frequency has been hypothesized for Southwestern ecosystems (Foster 1917; Humphrey 1958; Swetnam 1990). Additionally, decline in local Native American populations (and their burning practices) around 1860 may also have been important (Vankat 1977;

**Table 1**—Fire interval estimates from the 12 pine sites and eight sequoia sites from the year 1700 to 1900, giving the number of fires, mean fire interval (MFI), number of trees used in chronology development, and elevation (m). The long mean fire interval estimates for sequoia for this period are primarily a result of the decline in fire occurrence in Giant Forest beginning in the early-to-mid nineteenth century, generally earlier than in pine sites (see Fig. 3).

| Pine Site | No. | MFI | N | Elev. | Sequoia Site | No. | MFI | N | Elev. |
|---|---|---|---|---|---|---|---|---|---|
| HSR | 24 | 7.75 | 12 | 2180 | CMN - sequoia | 6 | 32.4 | 5 | 2103 |
| GFP | 20 | 9.65 | 9 | 2133 | CMC | 5 | 22.0 | 4 | 2097 |
| HUK | 26 | 6.58 | 6 | 2000 | LMN | 8 | 22.3 | 5 | 2090 |
| BOE | 16 | 10.65 | 5 | 1940 | CME - sequoia | 7 | 26.0 | 6 | 2073 |
| BOW | 22 | 7.82 | 4 | 1940 | CMW - sequoia | 6 | 31.2 | 4 | 2060 |
| MOR | 28 | 6.57 | 12 | 1940 | LME | 7 | 13.8 | 4 | 2045 |
| CMN - pine | 41 | 4.68 | 6 | 1670 | HKW | 11 | 15.8 | 3 | 2045 |
| CCR | 29 | 6.62 | 14 | 1640 | HKE | 6 | 22.6 | 2 | 2030 |
| CMM | 31 | 5.77 | 6 | 1640 | | | | | |
| CMW - pine | 41 | 4.78 | 6 | 1640 | | | | | |
| CME - pine | 37 | 5.24 | 7 | 1640 | | | | | |
| APR | 42 | 4.64 | 4 | 1575 | | | | | |

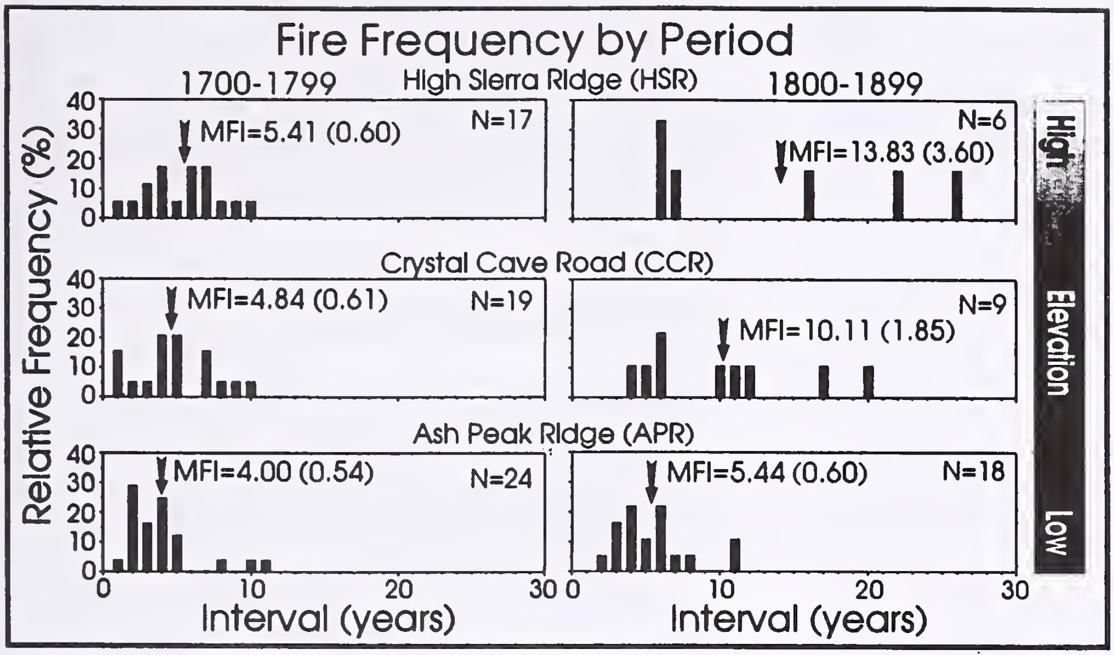


**Figure 4**—Frequency distributions of fire intervals for the 1700's and 1800's at three sites representing low, medium, and high elevations along the transect. Mean fire intervals and standard errors (in parentheses) are also shown.

Kilgore and Taylor 1979). Given the specific life history attributes of each plant species, such shifts in fire frequency over time have important implications for mortality and recruitment patterns within an ecosystem, with long-lasting consequences for vegetation structure and composition. Furthermore, the historical fact that shifts in fire frequency occurred prior to European settlement suggests that these systems have been dynamic for many centuries.

Fire regimes also varied spatially along the elevational transect (Fig. 4). As elevations increased along the transect there was a general increase in mean fire interval and an increased range in the fire frequency distribution. The mean fire interval differences across the gradient may not be as ecologically important as differences in the fire interval distributions. These distributions have important ramifications for ecological patterns because the life history attributes of many plant species are closely tied to their tolerance and intolerance to fire (Noble and Slatyer 1980; Zedler and others 1983; Bradstock and Myerscough 1988). While the mean fire interval value only gives a simple estimate of fire intervals at a specific site, consideration of the fire interval distribution provides a more complete characterization of the range and inherent variability in a fire regime. This variability is also important in designing prescribed burning programs because fire regimes with a similar mean fire interval could have very different fire interval distributions that might produce distinct differences in fire effects and vegetation responses.

Another important component of fire regimes is seasonality of fire occurrence. Seasonal fire-scar positions at the sampled sites were almost always found in the latter portion of annual rings (Fig. 5). This indicated that most fires occurred late in the growing season, probably from mid-summer to early fall. Accurate seasonal interpretation of these scar positions requires tree phenology studies to characterize tree-ring growth within a year at different locations and elevations along the transect. However, recent fire events of known dates provided us with benchmarks upon which to evaluate the seasonal position of scars produced by these events. The scar positions agree well with existing records of lightning and fire occurrence in the Sierra Nevada recorded since the beginning of the twentieth century. The peak period of lightning ignitions is between July and August with the greatest area generally burning in August, although large fires

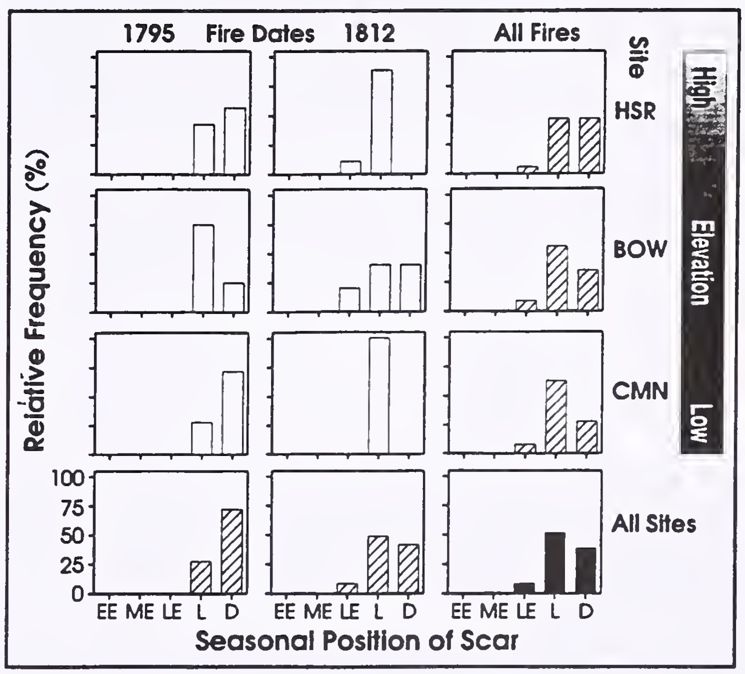


**Figure 5**—Histograms of the seasonal timing of past fires based on fire scar position within an annual ring. Data shown are for three sites and all sites combined for fires recorded in 1795 and 1812, and for all fire dates recorded along the transact combined. Site abbreviations are: HSR (High Sierra Ridge), BOW (Bobcat West), and CMN (Cedar Creek).

may occur at any time between June and September (Show and Kotok 1923; Parsons 1981; Vankat 1985). The peak in lightning ignitions occurs during the period of low and decreasing foliage moisture content, maximum temperatures, and minimal precipitation (Parsons 1981).

## SUMMARY

Well dated and replicated fire histories, extending back to the year 1700, were reconstructed for 12 sites. These histories document the occurrence of widespread fires with temporally variable fire frequencies. Fire frequency was inversely related to elevation; frequencies were relatively high in low-elevation forest stands compared to higher elevation stands. The highest fire frequencies were observed in the mid-to-late 1700's, followed by a decline in fire occurrence that accelerated around the beginning of the settlement era, with a nearly complete cessation of fires by the start of the twentieth century. Decreases in fire frequency also occurred earlier at higher sites. Major fire years were recorded at many sites as synchronous fire dates across most of the elevational transect in the years 1729, 1755, 1770, 1795, 1812, 1856, and 1873. Our observations of intra-annual positions of fire scars within the tree rings indicate that past fires usually occurred late in the growing season.

Knowledge of past fire regimes is important to managers in developing and implementing appropriate resource management policy (Fischer 1985; Parsons and others 1985). For one, fire histories provide basic information, such as past frequency and seasonality estimates of past fires. Secondly, they give a better understanding of how fire as a landscape-shaping process has changed since the "natural" fire regime has been altered. This information is necessary in the planning and management of prescribed burning programs, which require an understanding of the effect of past fire exclusion and what some of the fire effects and vegetation responses might be if fire is reintroduced.

Our findings underscore the importance of historic fire patterns across elevational gradients, forest types, and current management boundaries. Fire spread patterns across these gradients and boundaries in pre-settlement times were probably an important mechanism of ecosystem connectivity, influencing many different ecosystem processes and structures. Re-establishing this connectivity may be especially important in conditions of changing climate, because landscape connectivity may facilitate biotic adjustment in space and time to new environmental conditions. This will require fire management plans to include (and even encourage) burns of greater size and frequency than those that have been accomplished in the past two decades.

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# GIS Applications in Wildland/Urban Interface Fire Planning: The Missoula County (Montana) Project

Kelly R. Close
Ronald H. Wakimoto

The location of homes and vacation dwellings in and adjacent to areas prone to wildfire is known as the "wildland/urban interface." It poses a significant problem for fire protection needs because of the divergent fire suppression capabilities required to deal simultaneously with structure fires and wildland fires, and is an ever-increasing threat in Missoula County. Due to the potentially limited availability of fire suppression forces during the peak of a fire season, and the difficulties of fire suppression posed by the presence of homes in high-risk areas, the development of a comprehensive information base for areas in and near the wildland/urban interface is vital for effective fire management and protection planning.

The very nature of interface areas almost precludes the possibility of adequate fire protection. Structural fire protection in most interface areas comes primarily from rural fire protection districts and volunteer fire departments. Funding for these types of organizations is typically limited, and is inadequate to address the complex needs of interface areas. The result is a great disparity between many property owners' perceptions and expectations for fire protection and the reality of strategies developed by local fire service organizations.

Historically, catastrophic interface fires have occurred under extreme usually windy burning conditions. Wildfires quickly escape initial suppression efforts and overwhelm even the most coordinated fire suppression efforts. Wildland fire protection agencies are unable to contain the fires, spread is rapid, and structure protection resources are quickly exhausted. As has been vividly shown many times over in large, disastrous wildland/urban interface fires, there is often little that can be done once a fire escapes initial attack, available resources are quickly overwhelmed, and within a few short hours, destruction can occur on a large scale.

## THE "INTERFACE" SCENARIO IN MISSOULA COUNTY

Wildland/urban interface areas in Missoula County present particular difficulties in terms of fire management strategies due to their proximity to resource management and wilderness areas. This has made it necessary to consider residential and urban planning issues in wildland fire management planning.

The diversity of land ownership and use within Missoula County has resulted in highly divergent, and often conflicting, fire protection needs and responsibilities within relatively small areas. Missoula County has a large number of diverse interface areas throughout the county, from smaller communities protected by rural fire districts to the more urbanized areas of the Missoula Valley. New construction is continually progressing in and near heavily wooded areas, often adjacent to designated Wilderness Areas and commercial timber lands. Wildfires originating in interface areas can significantly impact wilderness areas and commercial timber lands, important parts of the local economic base, and fires originating in forested areas threaten the lives and property of people living in the interface.

Missoula County is characterized by a very decentralized type of governmental control; structural fire protection is provided by a complex mixture of local jurisdictions. Most of these are "rural fire districts," which in Montana are independent taxing jurisdictions in unincorporated portions of the county. Rural fire districts are separate from county government, and each is governed by a separate elected Board of Trustees (MCA, 1991; Ch. 7). The fact is constituents in Missoula County generally want decentralized authority (Dussault, 1987). County Commissioners are simply not going to devise rules and regulations to deal with the interface problem unless there is substantial support from the public. Solutions are generally reactive rather than proactive. Too often, it takes a disaster to generate public support, as with the Pattee Canyon fire in 1977 that burned over 1,200 acres and destroyed six homes (Holloron and Fleming, 1977).

## WILDLAND/URBAN INTERFACE AND GIS

A geographic information system (GIS) is a computer-based system for storing, retrieving, transforming, and analyzing spatial data. A GIS has the capability of linking map features with a variety of database attributes and performing spatial analysis. As such, it is an ideal tool for wildland fire management planning, which is largely a spatial problem.

Analysis of "spatial risk," or expected fire occurrence over an area, can be used to provide needed information such as where and how frequently wildfires can be expected to occur in the future. Spatial risk analysis is essentially a means of quantifying the probability of an unwanted event

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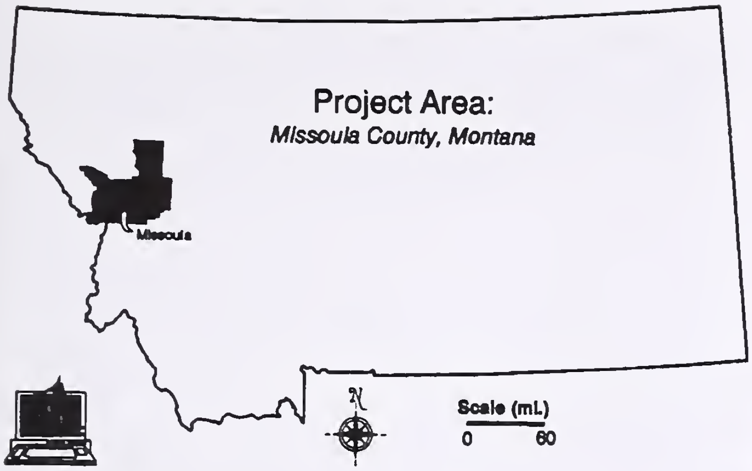


Figure 1—Project study area.

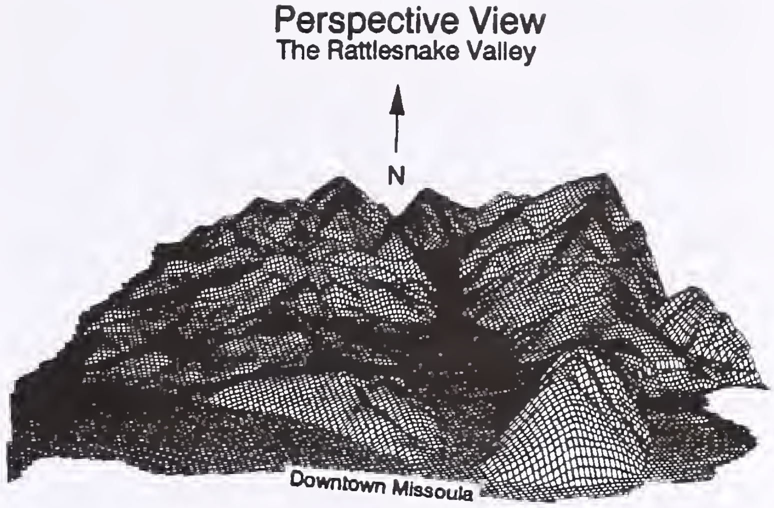


Figure 2—The Rattlesnake Valley: location of roads and structures.

(such as a wildfire) occurring in a specific place during a specified time period. If one or more wildfires have historically started in a particular area with a certain set of biophysical characteristics, it is likely that wildfires can also be expected to occur in the future, with a certain probability, wherever the same set of environmental conditions exist (Phillips, 1977; Doolittle, 1978). Problem areas tend to have distinct, unique characteristics that lend a certain degree of predictability.

Spatial hazard analysis also permits evaluation of the interrelationship of topography, vegetation, past fire occurrences, and values-at-risk. Spatial and temporal distribution and trends of fire in the interface can yield valuable information as to where and when problems will likely occur in the future (USDA Forest Service, 1987).

The primary study area for this project encompasses all of Missoula County, Montana (Fig. 1). A smaller area near Missoula, the Rattlesnake Valley, was chosen for a more detailed analysis (Fig. 2).

## MISSOULA COUNTY

Missoula County encompasses an area of 2,625 square miles (1.7 million acres or 679, 887 hectares) and ranges in elevation from 2,900 feet to over 10,000 feet (Fig. 3). The total population of Missoula County is approximately 78,000; most residents live in the Missoula Valley. Land uses and management strategies are highly diverse. Within Missoula County lie part or all of four federally designated Wilderness Areas, large tracts of commercial timberlands, agricultural areas, scattered residential developments, heavily subdivided areas and commercial zones. Land ownership is primarily a mixture of private and private-industrial (timber) ownership, the state of Montana, and several federal agencies. This has resulted in highly divergent fire protection responsibilities and land management strategies within a small area, which poses unique challenges in terms of fire protection and management strategies.

### Fire Protection

In Missoula County wildland fire protection is provided primarily by the Forest Service, Bureau of Indian Affairs, and Montana Department of State Lands. Structural fire protection is provided by seven rural fire districts, a municipal fire department, a fire service fee area, and two volunteer fire companies. According to Montana state law, rural fire districts and municipal fire departments are responsible for all fires, structural and wildland, within their respective jurisdictions (MCA, 1991; Ch. 7). However, wildland fire suppression capabilities and objectives for these local fire service organizations differ significantly from those of wildland agencies.

Unlike rural fire districts or municipal fire departments, fire service fee areas are responsible for suppressing only structure fires within their jurisdictions and are funded by a fee assessed per structure, rather than a levied tax. Volunteer fire companies have no jurisdictional areas, but nevertheless provide some fire protection to their communities.

### Vegetation

Vegetation is as diverse as land uses. In the valleys, the predominant vegetation is either agricultural crops or open grassland. As one progresses out of the valley bottoms, grasslands give way to heavily timbered slopes. At the uppermost elevations, steep, rocky slopes dominate the landscape, particularly in the designated Wilderness Areas.

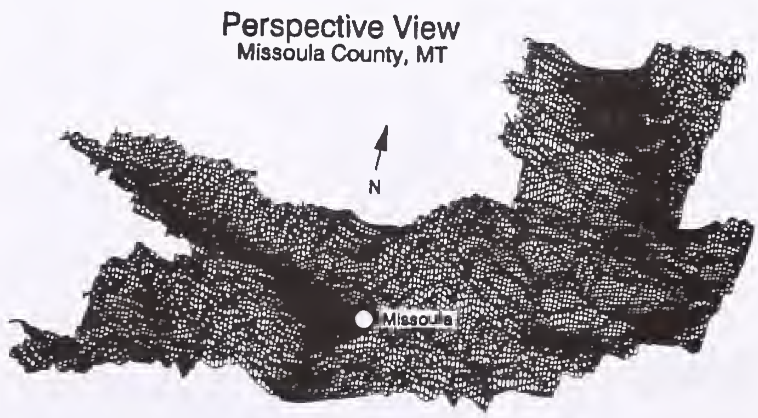


Figure 3—Perspective view of Missoula County, indicating general terrain.

## The Rattlesnake Valley

The Rattlesnake Valley lies north of downtown Missoula. Residential development varies from high-density suburbs adjacent to the urban core of Missoula to scattered residences bordering the federally designated Rattlesnake Wilderness (Fig. 4). As the valley floor of the Rattlesnake has become more congested with development, growth has continued to spread into the wooded slopes surrounding the northern part of the valley.

Controversy is prevalent in the Rattlesnake. Recent issues have included land use designation, preservation of open space, proposed housing developments, and fire protection. The issue of local fire protection has been of particular concern in the wake of annexations by the City of Missoula and the uncertainty of the future of the Missoula Rural Fire District station located in the heart of the Rattlesnake Valley.

## Fire Protection

Structural fire protection in the Rattlesnake is provided by both the Missoula [City] Fire Department and the Missoula Rural Fire District, with automatic mutual aid in existence for much of the valley. Wildland fire protection is provided by the Montana Department of State Lands and the Forest Service; the Missoula Fire Department and the Missoula Rural Fire District have wildland protection responsibility within their respective jurisdictions, and there is considerable overlap between wildland and structural agencies in the upper portion of the Rattlesnake. There are also areas on the periphery of the Rattlesnake that have no existing fire protection of any kind.

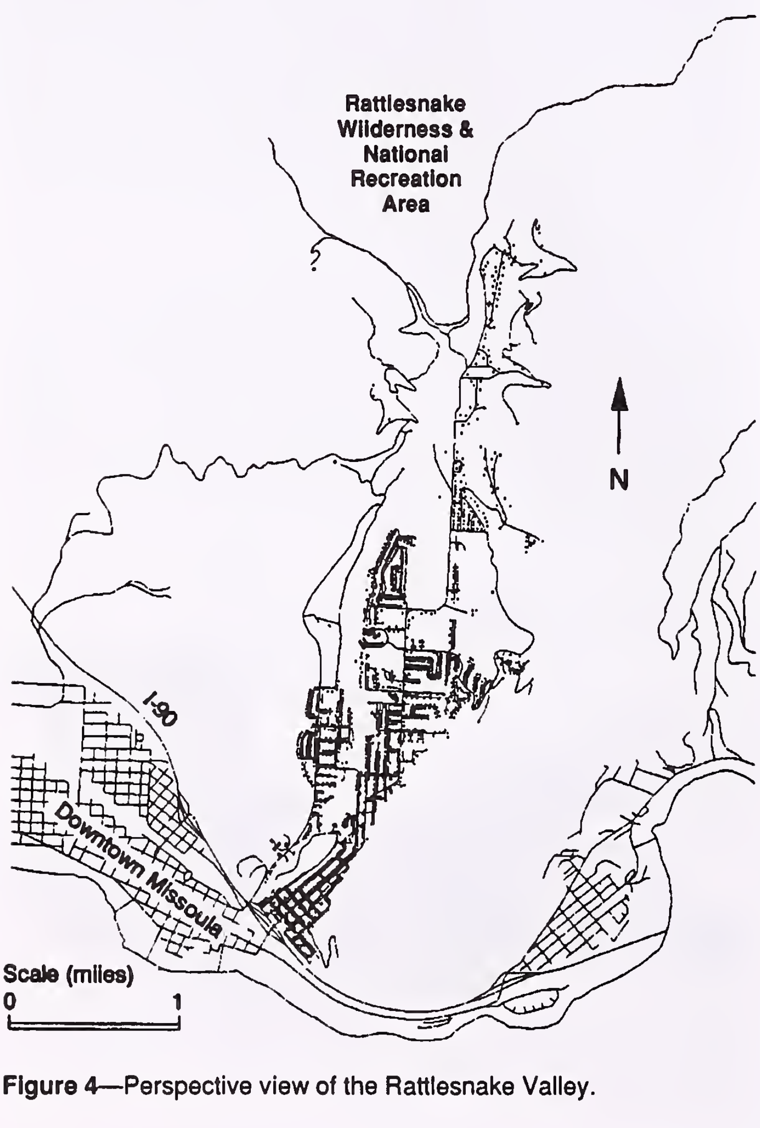


Figure 4—Perspective view of the Rattlesnake Valley.

## Vegetation

Natural vegetation within the Rattlesnake is nearly as diverse as in the rest of Missoula County. It includes grasslands, densely wooded riparian zones adjacent to Rattlesnake Creek, and heavily timbered slopes in the upper reaches of the valley. In the more densely populated parts of the valley, nearly all native vegetation has been replaced with landscaped, less flammable vegetation. However, many of these neighborhoods lie in close proximity to highly flammable native vegetation.

## PROJECT OBJECTIVES

This study demonstrates the use of a GIS to perform spatial and temporal analyses of the various factors important to wildfire hazard, risk, and planning in and near wildland/urban interface areas. Through this analysis, zones of "interface" and "non-interface" areas are being delineated and characterized. Map layers and associated databases include features such as topography, wildland fuel types, past fire occurrence and cause, characteristics of wildland and structural fire protection, road locations and types, and demographic information.

The analysis is being performed at two levels of resolution:

(1) A "broad-brush" assessment of the entire county.

(2) A detailed evaluation of a single drainage, the Rattlesnake Valley. The developed areas of the valley cover about 10 square miles, and range from high-density residential development adjacent to an urban zone to scattered structures bordering the federally designated Rattlesnake Wilderness Area. This portion of the study includes mapping and classification of individual roof types, by their relative flammability, for the 1,870 structures within this drainage, and an appraisal of surface water supply for suppression operations.

From this analysis, current and potential problem areas are being identified and characterized. Used as a baseline for pre-suppression and prevention planning, the results of this analysis will potentially help local fire managers reduce the occurrence and intensity of wildfires by targeting specific areas for fire prevention and hazard mitigation programs. In addition, it will facilitate effective contingency planning for initial response to wildland/urban interface fires, as well as more effective management of large incidents.

The focus of this project is in several major areas.

## Hazard

Hazard is defined as the amount of available fuel that can burn and contribute to the spread and intensity of a wildfire, given an ignition source. For this analysis, hazard has been quantified by expected flame length. Flame length was chosen as an indicator of hazard due to its correlation with fire intensity (Albini, 1976). A composite overlay

of information layers consisting of wildland fuel types (Anderson, 1982), slope, and aspect was generated at a resolution of 10 acres (county-wide) and one acre (Rattlesnake Valley). Using two sample sets of weather parameters, flame length output was generated using the BEHAVE fire behavior prediction program (Burgan and Rothermel, 1984). Maps were generated depicting expected flame length for surface fires. "Hazard" is then readily delineated, quantified, and assessed in relation to risk and values-at-risk.

## Risk

Risk is defined as any potential ignition source that can start a wildfire. Risk and hazard together serve as indicators of the potential for a destructive wildfire. For the sake of simplicity, actual fire occurrences were used to delineate risk. For a 10-year period (1981-1990), individual fire occurrences were mapped for the entire county. Fire records were obtained from all federal, state, and local fire protection entities within Missoula County.

Within the associated database, information was included concerning the cause category (human or lightning), as well as specific cause sub-classifications, date and time of fire occurrence, fire size, responsible agency, and so forth. During this period, there were 2,700 wildfire occurrences reported. Of these, 67% were human-caused and 33% were lightning-caused.

Human-caused fires appear to be closely associated with human developments and activities. This fire occurrence information layer is being assessed in relation to other information such as population distribution (1990 census data), proximity of wildfire occurrences to human improvements (roads, railroads, and powerlines), and predominant land use and ownership. This spatial risk analysis will be used to derive a predictive model to asses expected trends in human-caused fire occurrence as a result of development of improvements in a given area. Potential impacts on fire protection and fire management programs can then be assessed and included in planning efforts.

For the spatial risk analysis, this fire occurrence information is being assessed in relation to population density, proximity to roads and other improvements, and predominant land use and ownership. The intent is to derive a predictive model in order to determine the potential impacts on anticipated changes in fire occurrence (and, therefore, fire management programs) resulting form future developments in wildland areas.

## Pre-Suppression and Operational Considerations

There are a number of other purposes for which a GIS can serve as a valuable planning tool in fire management. Several of these are currently being examined for the Missoula County project:

**Response Time From Fixed Locations (Fire Stations)**—In Missoula County, local fire service organizations are generally the initial responding units to interface fires, and unlike many wildland suppression resources, respond from a fixed location. Using a "network analysis" function within the GIS, response time maps are being generated. Roads have been classified into six categories by surface type and estimated typical travel speed. Elevation and slope information from the digital terrain models are being used to derive the slope of each road segment, and maximum weight capacity is included in the road database for each bridge location. This information allows for the generation of maps showing areas that are inaccessible to certain responding apparatus.

**Water Supply From Hydrants**—For the Rattlesnake map, individual hydrants have been mapped, and information in the associated database include (1) the gallons-per-minute rating, and (2) pressure rating (flow, static, and residual pressures as determined by fire department test in 1991). Using pre-determined parameters for hose diameters, water flow, and apparatus configurations, the "effective water supply" areas are being delineated. Mathematical formulas for friction loss in hose lines are being used in conjunction with the slope map and other information layers for this analysis. The resulting derived map layer will depict areas that require alternative water supply sources for fire suppression operations in interface areas.

**Jurisdictional Areas of Fire Protection Agencies**—In Missoula County, boundaries of wildland and structural fire protection areas are complex, and extensively intermingled, particularly in interface areas. This poses additional potential complications as fires cross jurisdictional boundaries. In many situations, overlapping wildland and structural jurisdictions are adjacent to areas with no existing fire protection.

From overlays of fire protection jurisdictions and special land use designations, such as wilderness, themed maps are being generated depicting the nature of fire protection scenarios throughout the county. This allows fire personnel to address organizational complications before these situations are encountered in an emergency situation.

## Prevention/Pre-Planning—Hazard Mitigation

Each house in the Rattlesnake has been mapped, and information regarding the relative flammability of the roof is included in the database. Using slope, elevation, and fuel type maps, zones of hazard abatement (fuel modification) are being created for each structure or group of structures. The extent of the zones generated will account for slope (particularly distance downslope from the structures), flammability of the roof materials, and proximity to high-hazard areas.

# METHODS

## System Used

The computer system used fro this project is a PC (Personal Computer) system based on the Intel 80486 processor. The GIS software being used is PAMAP and FOXPRO is the database management system.

**Table 1**—Description of primary and derived map layers for analysis

| Initial Map Layer | Derived Information Layers |
|---|---|
| Digital elevation model | Slope and aspect maps<br>Perspective views |
| Roads, powerlines, railroads | Distance corridors for proximity analysis of fire occurrences |
| Fire service organization and wildland fire protection | Existing fire protection systems |
| Population density | Spatial relationships of population distribution to fire occurrence (risk), delineated hazard zones, and existing fire protection |
| Road network | Network analysis: "Response time zones" from existing fire stations. Access—effects of bridge capacities and road grade |
| Structures (Rattlesnake) | Defensible space/hazard mitigation zones |
| Fire hydrants (Rattlesnake) | Effective surface water supply area. Based on the maximum distance of water flow in hose lines from hydrants, given an initial flow rate and pressure, and friction-caused pressure loss over distance in hose lines. |
| Slope<br>Aspect<br>Fuels [BEHAVE* model] | Fire behavior maps: rate of spread, fire intensity, flame length |

* Burgan and Rothermel, 1984

## Information Layers and Database Attributes

Initial map layers have been built, and associated databases include specific information regarding map attributes. From these, new layers for further analysis have been derived as shown in Table 1.

Input from local fire managers has been solicited through periodic meetings with representatives from Missoula County fire protection organizations during the course of this project. This has been a key part of the project in obtaining vital input from "end users," and ensuring that the final analyses provide information needed by fire management personnel, as well as other potential users (such as land use planners).

## SUMMARY

The real key to finding solutions lies in cooperative efforts in planning and hazard mitigation, well before a potential disaster strikes. To this end, the development of a comprehensive geographical information base for wildfire hazard assessment and risk analysis is vital for effective planning for fire prevention, hazard mitigation, and land management. This process necessarily needs to accommodate wildland, rural, and urban land management strategies and philosophies. This is due to the complexity of fire management and resource protection strategies in the wildland/urban interface, and the unique and diverse needs of fire protection personnel in each agency at numerous levels of planning.

The GIS-based inventory developed in this project will provide specific information on each area to Missoula County agencies involved in urban interface fire protection. The wildland/urban interface issue, by its very nature, is a dual responsibility of wildland fire managers and structure protection agencies. Therefore, a GIS that can target specific "mutual threat" zones may also serve as a foundation for future cooperative efforts between fire protection organizations.

## ACKNOWLEDGMENTS

This project is funded by the Blackfoot Forest Protective Association and the McIntire-Stennis Forestry Research Program.

Jon Skinner and Gabi Archibeque have provided valuable assistance in the collection and input of data for this project, as have numerous people from many of the local, county, state, and federal agencies in Missoula County who provided the necessary data, maps, information, and advice for this project. Ken Wall and Joe Grigsby have also been very helpful in providing data, map information, and technical assistance.

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# Protecting Structures in Parks and Wilderness

Jack D. Cohen
James M. Saveland
Richard A. Chase

Structure fire protection during a wildland fire is often regarded as a residential problem of the wildland/urban interface. However, our parks and wilderness areas contain structures that facilitate and enhance visitation; they also possess cultural value. Such structures, including backcountry bridges, lodges, and visitor centers, can be destroyed by wildfires and prescribed natural fires.

The related management task obviously becomes one of preventing a structural fire loss. How to accomplish the wilderness and park structure fire protection with a minimum amount of site disturbance might not be as obvious. One aspect of preventing structure fires is to remove and modify the vegetation around structures. However, managers have largely had only intuitive guidance in determining the extent of vegetation modification for structure protection.

Recent research may provide additional guidance for vegetation management around structures. Research for the development of the Structure Ignition Assessment Model (SIAM) suggests that extensive vegetation management may not be necessary to reduce the chances of structure ignitions. Preliminary results from SIAM and supporting laboratory experiments indicate that the heat transfer from flames, particularly from wildland fires, is not very effective for igniting structures.

## STRUCTURE IGNITION ASSESSMENT MODEL (SIAM)

A systematic, analytical modeling method is under development to rate structure ignition risk in the wildland/urban interface (Cohen 1991; Cohen and others 1991). Although SIAM focuses on the wildland/urban interface situation and thus, mainly a residential context, its computations generally apply to a structure's exterior when exposed to flames. Figure 1 describes the general SIAM computational process involving the inputs, calculation modules, and the risk rating output. Although an operational version of SIAM is not yet available, a research version has produced computational results, particularly regarding ignition estimates from flame radiation and convection. The model results indicate a surprising lack of sustainable ignitions from a wide variety of flame exposures.

## MODEL RESULTS

This discussion specifically regards the ability for flames to radiate a sufficient heat flux (heat flux is the amount of energy per unit time passing through a unit area) to produce sustained structure ignitions. The SIAM results specific to this discussion only involve computations of the thermal radiation incident to a wood surface and the heat flux necessary to produce a sustained ignition. These computations involve only the HEAT TRANSFER and IGNITIONS modules of SIAM. Detailed descriptions of these module calculations can be found in Cohen and others (1991) and Tran and others (1992).

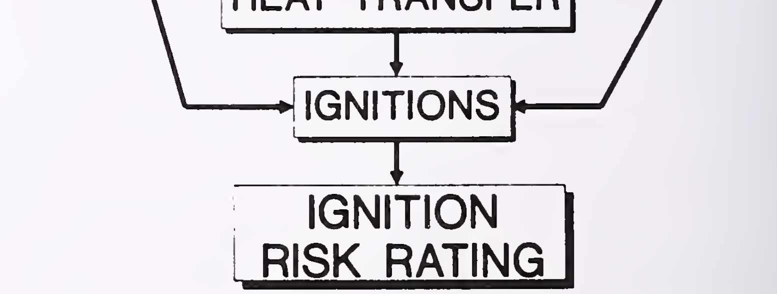


**Figure 1**—SIAM process diagram: inputs—Structure Design, Topography, Weather Conditions, Fuels; calculation modules—FLAMES (fire characteristics), HEAT TRANSFER (from flames, incident to the structure), Firebrands (structure's exposure to firebrands), IGNITIONS (from flame heat transfer and firebrands); output—IGNITION RISK RATING (estimate of relative likelihood of a sustainable structure ignition).

In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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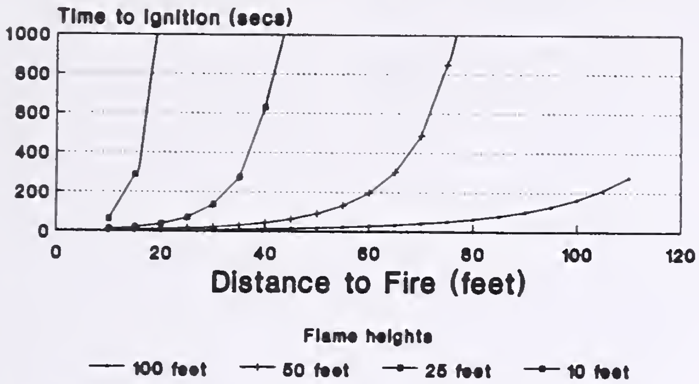
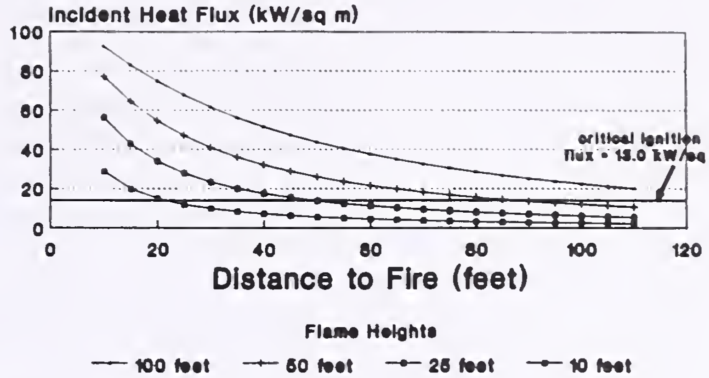
# TIME TO SUSTAINED IGNITION
## SIAM Ignition Model (piloted ignition)




500 ft. fireline length
.99 effective flame emissivity

Figure 2—Relating incident heat flux to the distance from the fire to the structure. Only a radiant heat flux is represented. Flame contact is assumed not to occur, thus, no flame convective heat flux is included.

# INCIDENT HEAT FLUX
## SIAM Radiation Transfer Model




500 ft. fireline length
.99 effective flame emissivity

Figure 3—Relating time to sustained ignition to the distance from the fire to the structure. The ignition is piloted, the ignition sustains after the heat source is discontinued, and the empirically based ignition model requires the incident heat flux rather than the net heat flux.

The computational results demonstrate a general relationship between the incident heat flux and the time to ignition as a function of the distance from a structure to a fire. The SIAM calculations do not simulate or predict an actual fire situation, but they generally show how the heat transfer and the resulting ignition time changes as a function of fire-to-structure distance. For the purpose of this demonstration it is assumed that:

- the flame-structure geometry is generalized to be directly opposed, parallel surfaces;
- flame temperatures are uniformly 1,200 Kelvin;
- flame emissivities are uniformly equal to 0.99;
- the flame height is the vertical projection of the flame length;
- the fireline length is straight, uniformly continuous, and extends 250 feet (76.2 meters) on either side of a structure's midpoint;
- no convective heat transfer occurs.

## Relating Incident Heat Flux to Distance to Flame

Figure 2 provides a description of the resulting heat flux, given the flame height and the distance between the flame and the structure. For example, given a distance of 30 feet (9.1 meters) and a flame height of 50 feet (15.2 meters), the heat flux is slightly greater than 40 kilowatts/square meter (kW/sq m). The solid horizontal line at 13 kW/sq m represents the minimum heat flux required for a sustained ignition (ignited fire continues after heat source removal) after a very prolonged exposure. In contrast, human skin exposed to 6.4 kW/sq m results in pain after 8 seconds (Drysdale 1985). Figure 3 provides further interpretation of the heat fluxes in terms of the time required for sustained ignitions.

## Relating Time to Sustained Ignition to Distance to Flame

The time required for a sustained ignition described in figure 3 is calculated using the heat fluxes described in figure 2. The time to ignition assumes the presence of a pilot igniter, which requires less heat flux than a nonpiloted ignition. Sustained ignition implies that flaming of the exposed wood continues after the initial heat source has discontinued. As the distance to the flame increases for a given flame height, the incident heat flux decreases; thus, the amount of time required for ignition to occur increases. For example, using figure 3, the 10-foot (3.0 meter) flame height that is 10 feet from a structure produces a sustained ignition in approximately 60 seconds. At 20 feet (6.1 meters), the incident heat flux has decreased to nearly the critical ignition flux (from fig. 2), and the time to ignition is greater than 1,000 seconds. In contrast, an incident heat flux less than 13.0 kW/sq m does not result in sustained ignition; skin exposed to 11.0 kW/sq m results in pain in less than 3 seconds (Drysdale 1985).

## DISCUSSION

This discussion only relates generalized flame characteristics to sustained structure ignitions due to direct flame radiant heat transfer. The graphs illustrate that a sustained structure ignition requires an incident heat flux above a minimum amount along with a minimum time before ignition. The time to ignition decreases as the heat flux increases.

Convective heat transfer is not included. In general, sustained ignitions do not result from convective heat transfer unless flame contact occurs. The closest flame distance used for the radiant computations is 10 feet (3.0

meters), so that no flame contact occurs. However, ignitions due to convective heat transfer also have a heat flux/time-to-ignition relationship. Tran and others (1992) show a similar heat flux/time relationship for experimental results where convective heat transfer dominates during flame contact.

Sustained ignitions occur only if the flame source continues for a sufficient duration. For a sustained ignition to occur, a flame must be sufficiently close to a structure; it must provide a heat flux such that the time to ignition is shorter than a fire's active flaming duration. Generally, in wildland and landscaping vegetation, the small live and dead fuel size classes in porous fuel beds produce the highest burning intensities (exceptions would be slash, wood piles and other structures). However, these fine fuel beds have relatively short active flaming times, on the order of seconds to minutes. Using porous, homogeneous, dead fuel beds, Anderson (1969) relates the active flaming time (residence time) of the spreading flame zone (in minutes) to be approximately eight times the fuel particle thickness (in inches). For example, at a specific location, a fuel bed made of one-eighth inch (3 millimeter) dead fuel particles would be expected to have an active flaming residence time of one minute. Based on computations from the Fire Behavior Prediction System (Andrews 1986), the greatest residence time estimate from the 13 standard fuel models is .34 minute, or about 20 seconds.

Comparison of expected flaming residence times and the time required for ignition at various heat fluxes provides a guide for protection needs. Examination of figure 3 indicates that for a burning duration of 5 minutes, the most severe case (100-foot [30.5 meter] flame heights) does not produce sustained ignitions at distances greater than 120 feet (36.6 meters). For a residence time of 1 minute or less, sustained ignitions for 100-foot flames would be expected at a distance of approximately 80 feet (24.3 meters). The time to ignition varies by heat flux, which depends on the flame height (fire intensity) and/or the distance between the structure and a fire. Vegetation management activities can remove fuels and thereby increase the structure-to-fire distance and can modify fuels to decrease the potential fire intensity (flame heights).

## CONCLUSIONS

Structure ignitions occur from either a flame's radiative and convective heat transfer, or from firebrands (as shown in the SIAM process diagram, fig. 1). Convective heat transfer does not result in ignition unless flame contact occurs. For ignition to occur from radiation, a flame must be sufficiently close to a structure such that the time to sustained ignition is shorter than a fire's burn-out time. The graphs above indicate that ignitions due to radiant heating during wildfire conditions are a short range problem (less than 120 feet [36.6 meters]). Firebrands are not limited to this short range. Firebrands that may result in an ignition can originate thousands of feet from a structure.

This suggests that actions to reduce the likelihood of structure ignition should focus on the structure and its immediate surroundings. Immediate surroundings can be operationally defined as that area where the severe fire potential can directly result in sustainable ignitions. For the most severe case used in this discussion, 120 feet from the structure would delineate the immediate surroundings. It is possible that extensive vegetation management beyond the structure's immediate site would be more than that necessary to prevent flame-caused ignitions, but insufficient to prevent ignitions caused by lofted firebrands.

Specific vegetation management activities depend on site-specific characteristics of the topography, structure, and fire potential. However, in general, three zones around a structure might be considered.

Zone 1—vegetation should be removed to eliminate the potential for flame contact with the structure.

Zone 2—vegetation should be modified to reduce potential fire intensities (thus reducing potential flame heights); remove heavy fuels to reduce flaming residence times; thin vegetation and prune where possible to reduce the potential for a continuous line of flaming vegetative canopies.

Zone 3—this area is at a distance where direct flame heat transfer does not result in sustainable structure ignitions; vegetation management might be used to decrease potential canopy burning and thus reduce a structure's firebrand exposure from close-range sources.

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# Fire Growth Modeling in the Sierra Nevada of California

**Mark A. Finney**

The fire growth model FARSITE (Fire ARea SImulaTor) is under development at Sequoia and Kings Canyon National Parks for purposes of simulating the spread of prescribed natural fires. This paper summarizes the state of the model as of March 1993 and the process begun to validate the technique.

The model treats fire growth as a spreading wave using equations for elliptical fire fronts developed by Richards (1989). Fire perimeters are represented by a series of points (X,Y coordinates). Calculations are made for each point to find their new positions after user-specified time-steps; collectively, these points represent the changing fire front. Under uniform conditions of topography, fuels, and weather, the fire spreads as an ellipse with eccentricity determined by the magnitude of the resultant wind-slope vector (Alexander 1985). The fire attains complex shapes, however, under actual conditions where all factors are heterogeneous.

The model requires data on topography and fuels, such as raster-based GIS (geographic information system) data themes. Weather information is currently input as files containing initial fuel moistures, daily temperature and humidity patterns, and wind changes. Temperature and humidity at an observation point were extended over the landscape as detailed by Rothermel and others (1986). Wind speed is modified for canopy coverage, but in the absence of a weather model, wind speed and direction are simply assumed to be constant during a time-step over all terrain.

To calculate fire perimeters over time, FARSITE uses fuel and topographic data from the raster nearest each point on the active fire perimeter(s). Weather and fuel moistures for that point are then computed from initial conditions using procedures developed for the BEHAVE fire behavior modeling program (Rothermel and others 1986) and the NFDRS (National Fire-Danger Rating System) (Bradshaw and others 1983). This was more computationally efficient than constructing a fuel moisture map (all cells on the landscape) at each time step. Using the wind-slope vector, forward rate of spread is calculated (Rothermel 1972) and elliptical dimensions determined (Alexander 1985). This information is used to compute the new fire front after the next time step (Richards 1989).

## CAPABILITIES

The FARSITE model can run on a personal computer. The user specifies weather and GIS files and then uses a mouse to input ignition points and/or active fire perimeters on the landscape. FARSITE accepts multiple fires, which can merge (Figure 1) and form inward burning fires (burning-out an island). FARSITE displays fire perimeters color-coded by fireline intensity. The user controls temporal and spatial resolution of fire growth. Area (ha) and perimeter length (m) of the fire(s) are calculated in horizontal and topologic units. The fire, terrain, and fuels can be viewed in two or three dimensions. Output image can be saved and retrieved.

## VALIDATION

Preliminary validations have been conducted using four prescribed natural fires and one wildfire occurring in Sequoia National Park. Terrain and fuels were obtained from GIS raster themes for landscapes surrounding each fire. Weather data were obtained from RAWS (remote automatic weather stations) stations near the fires or input from fire weather observations. Reduction factors were found to be necessary for obtaining realistic temporal scaling of rate of spread from the Rothermel (1972) model when applied to large spatial scales (hundreds to thousands of hectares) and temporal scales (days to weeks) of the prescribed natural fire simulations. These factors were defined by fuel type at the beginning of the simulation based on comparisons with measured spread at the head of the actual fires. Reduction factors varied from three to five for timber and grass fuel models up to 10 for some shrub fuel types and fires. Since fuel moistures in the simulations were close to measured values, these large reduction factors are interpreted as relating to the degree of spatial heterogeneity in fuels, and temporal and spatial heterogeneity in wind, all factors that are critical to fire spread but not accounted for by the Rothermel model or resolution of the data.

Similarity was assessed graphically (Figure 2) using easily obtained measures of area overlap, perimeter calculations, and rates of spread (radially from the ignition point). For each fire, actual perimeters were overlaid with modeled perimeters from comparable time-steps (Figure 3). Quantitative statistical comparisons will be made for these and for other fires from Sequoia and Kings Canyon and Yosemite National Parks.

In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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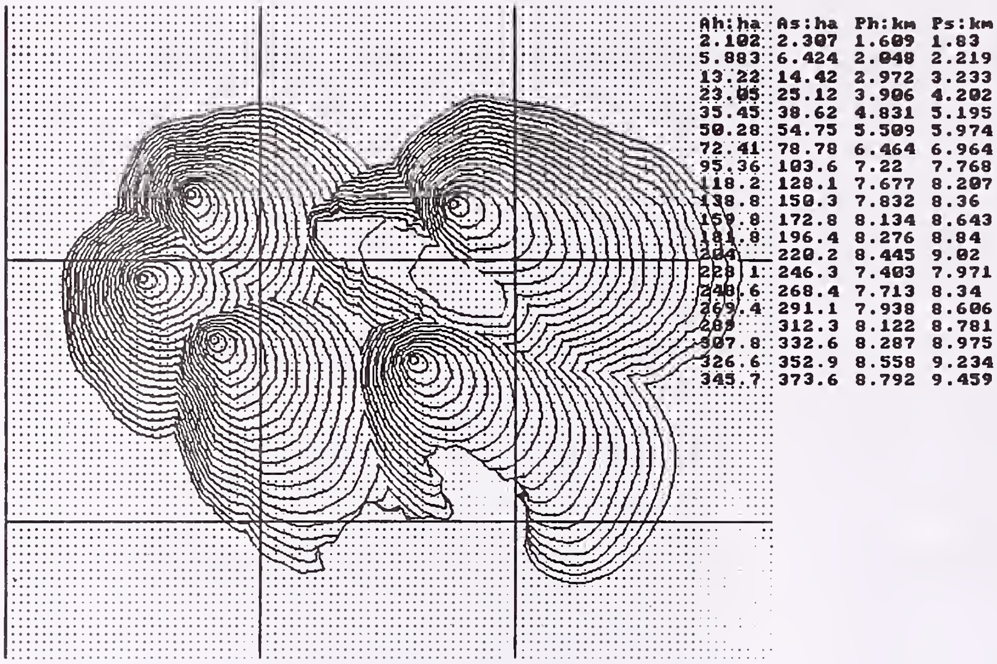


**Figure 1**—Example of two-dimensional output from FARSITE showing multiple ignition points and area (AH is area horizontal, AS is area surface), and perimeter (PH is perimeter horizontal and PS is perimeter surface) calculations at 4-hour time-steps. Fuels are NFFL (Nothern Forest Fire Laboratory) Model 8 except for a patch of Model 5 fuels with its higher rate of spread indicated by wide spacing between perimeters. The surface area and perimeter have been corrected for slope.

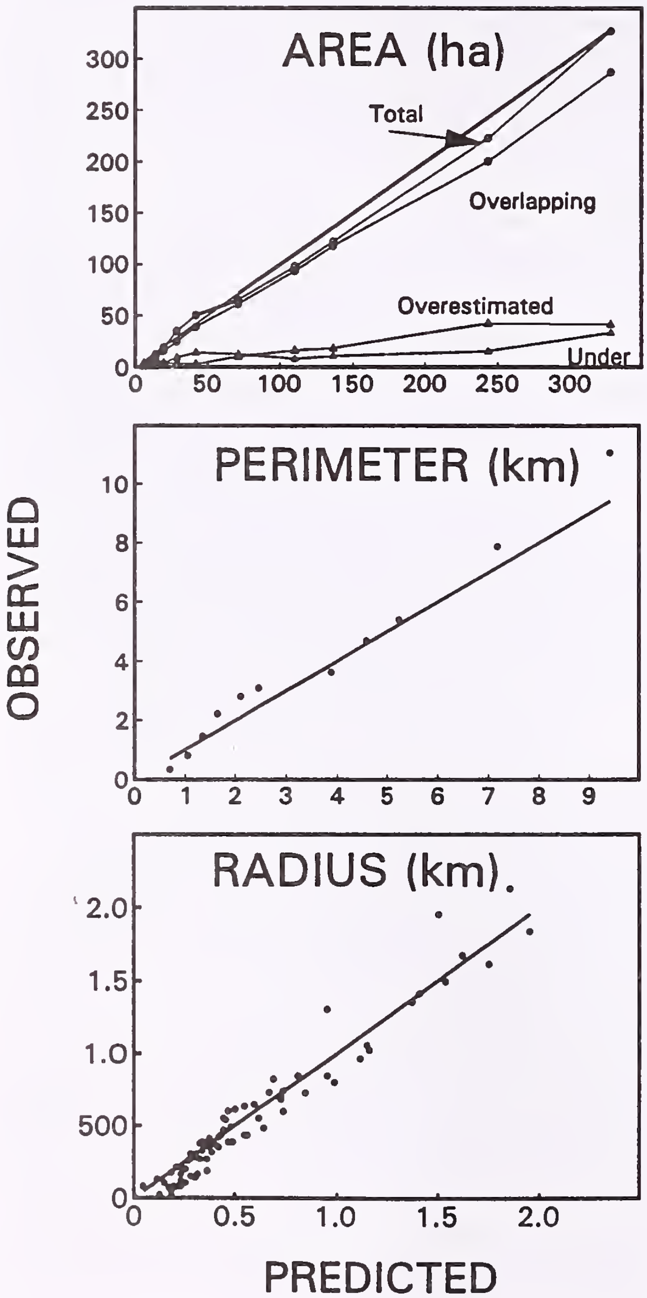


Figure 2—Comparison of predicted and actual fire spread for the Deercreek 1991 prescribed natural fire.

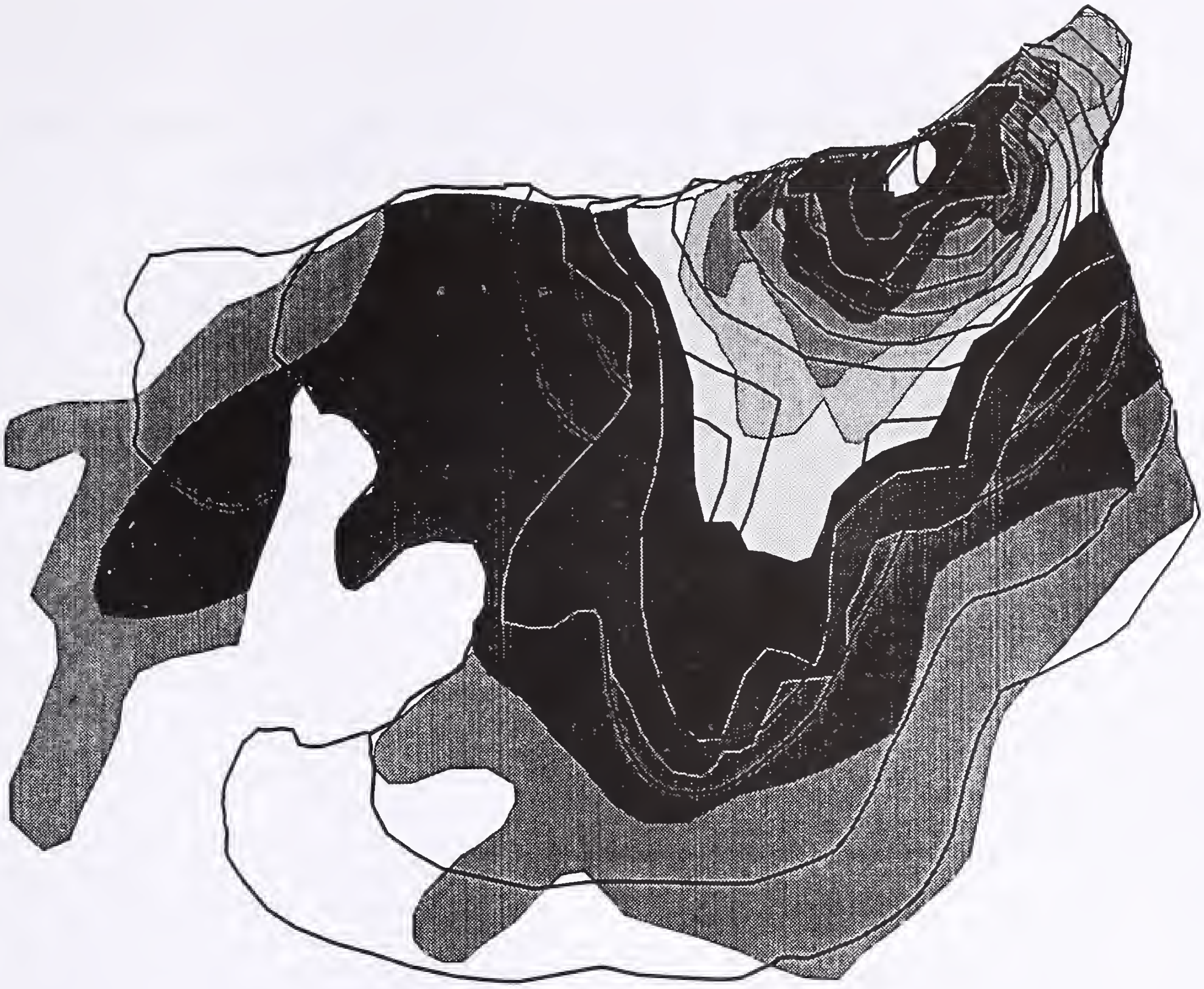

**Figure 3**—Overlay of perimeters for the Deercreek 1991 prescribed natural fire. Lines represent simulated perimeters; shaded areas represent actual fire spread pattern at equivalent time steps.

## CONCLUSIONS

The modeling approach used in FARSITE is a very efficient technique (computationally) for simulating fire spread under complex conditions. Simulations of fire spread over several weeks took approximately 30 minutes on a PC (personal computer) with a 25 MHz 80486 processor. Initial validations suggest that the technique is valuable for projecting fire spread patterns, given that rate of spread reduction factors can be determined.

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# An Analysis of the Process, Problems and Results Using the Yukon Flats National Wildlife Refuge Buttes Gap Experience as a Case Study

**M. Joan Foote**
**Fred Deines**

The Yukon Flats National Wildlife Refuge in interior Alaska undertook a prescribed burning program in 1985. Fire is considered a natural part of the boreal ecosystem, necessary to maintain the diversity of the habitats. Usually this is accomplished by using managed wildland fires to maintain a near natural fire regime in remote areas. The Yukon Flats National Wildlife Refuge was surveyed for areas where prescribed fire might be an appropriate tool. The Buttes Gap Site was one of four potential areas selected. The refuge with the assistance of the Alaska Fire Service developed, implemented and executed the Buttes Gap Prescribed Burn Plan. Our experience, evaluation and conclusions may be helpful to others interested in using fire for management purposes.

## THE PROCESS

The process was composed of the following steps:

(1) Initiate the idea or concept of using prescribed fire
(2) Define your management, resource, or research objectives
(3) Become familiar with all restrictions about where, when, and how you can burn that relate to your area of interest
(4) Write a prescribed burn plan
(5) Obtain permits and signatures required by your agency, your cooperators' agency, and state or federal government
(6) Implement the plan and conduct the burn
(7) Evaluate the experience and write summary reports.

Sounds easy—well it's not! To progress beyond step one, you must have the strong support of your supervisor and your agency. Step two is also critical. The more specifically you can state your objectives, the easier it is to determine the severity of burn you need and the type of fire needed to accomplish the burn. Step three evaluates all the restrictions. If you can not conduct the prescribed burn, then the process stops.

Step four is the preparation of the prescribed burn plan. It is supposed to lay out the plan for the burn and tie together all the information that you need to consider such as fuels, burning conditions, the type of fire, possible impacts on the site and adjacent areas, special constraints, the equipment and persons to conduct and safely control the fire. Contingency plans must be in place should the fire become a wildfire. The Buttes Gap prescribed burn plan included the following sections: background information, burn restrictions, site description, location, topography, soils and other factors that might relate to burning, resource objective, prescribed fire objective (specific), dead woody fuel descriptions, live fuels on and adjacent to the site, weather and fuel parameters, fire behavior, smoke management, special constraints, site preparation, ignition schedule and length, public information and contacts, firing and holding, safety hazards, important points for crew briefing, water sources, mop-up, work force and equipment, line authority, costs, history of previous fire, monitoring and evaluation, test burning, maps and supporting documents.

In addition to the internal agency review and signatures, an Open Burn Permit from the Department of Environmental Conservation was required in step five. A survey of archaeological sites, current trap lines, and the presence of endangered species was also required. These surveys and permits take time, especially when more than one agency is involved. New permits had to be obtained each year.

The more thoroughly you have completed steps one through five, the fewer last minute decisions and problems you will have in step six. The sooner the evaluation and summary reports are written, the more accurate their content and the greater their value.

## PROBLEMS ENCOUNTERED

The process takes time—it took four years to actually burn Buttes Gap. Selection of the prescribed burn site needs to consider all resource or research objectives. At Buttes Gap more consideration was given to the availability of existing data and research potential than to site burnability.

Meeting acceptable weather parameters proved difficult. Conditions during the fire season were variable—either too wet and cold or too dry and hot. Problems with ignition equipment led to one abort and another year's wait. The weather became unfavorable before the equipment could be repaired.

Commitment of all participants to the prescribed burn was not 100 percent. Periods of acceptable weather were

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bypassed because key people were not available—either assigned to other work or on leave. Composition of the firing team changed several times, so information and training had to be repeated. When the conditions were good for the Buttes Gap prescribed burn, they were also good for wildland fires. Suppression of the wildland fires took priority and diverted key people and equipment elsewhere.

During the ignition stage, the burn boss and aerial ignition team began ignition prior to the arrival of the land manager. Unfortunately the ignition team was disoriented and ignited part of the control site that was not meant to be burned. When the land manager arrived at the Buttes Gap site on burn day, radio malfunctions prevented interplane communication and the land manager was unable to have input into adjustment of the firing pattern.

## RESULTS AND DISCUSSION

The area to be treated by fire contained the following nine vegetation types:

- Open needleleaf white spruce forest
- Open needleleaf black spruce forest
- Needleleaf white spruce woodland
- Mixed white spruce-paper birch woodland
- Closed tall diamond willow scrub
- Open tall diamond willow scrub
- Open tall feltleaf willow scrub
- Open tall littletree willow scrub
- Wet herbaceous (wetland herbs).

Three pre- and post-burn fire effects surveys were conducted in the Buttes Gap area. They surveyed the vegetation types and fuel loads, small mammal populations, and water quality and waterfowl use.

Ignition of the Buttes Gap prescribed burn started at about 1 p.m. on July 9, 1989. A Mark III aerial ignition device (ping-pong ball machine) mounted in a helicopter was used for ignition. A partial burn was achieved and it self extinguished within three days, except for a few small areas which smoldered until late August. The burn was monitored by airplane throughout the remainder of the summer for possible flare-ups. About 1,200 acres was burned.

All forest and woodland types burned, but to varying degrees. Even after vigorous ignition attempts, none of the tall willow scrub types burned. Four of the nine upland vegetation/fuel and small mammal study sites burned. None of the wetland and waterfowl study sites burned.

The Buttes Gap Prescribed Burn had four prescribed fire objectives, seven resource objectives, and three research objectives. The prescribed fire and resource objectives were clearly written into the Prescribed Fire Plan, while the research objective was not.

### Prescribed Fire Objectives

Objective 1—Consume at least 50 percent of dead or downed fuels less than three inches in diameter. This objective was not achieved. In fact, downed fuels in the 0 to 3-inch diameter class increased 130 to 200 percent (Table 1).

**Table 1**—Quantitative data derived from the permanent vegetation study plots located within the perimeter of the 1989 Buttes Gap Prescribed Burn. Black spruce is abbreviated by BS, white spruce by WS.

| Attribute | White spruce Woodland | Mixed WS-Birch Woodland | Open BS Forest | Open WS Forest | Open Tall Willow Scrub | Wet Herb Types |
|---|---|---|---|---|---|---|
| | | | One Year Post-Fire Values as a Percent of Prefire Values[1] | | | |
| DDWF load 0-3 inch DC[2] | 151 | 198 | 174 | 130 | 0 | 0 |
| DDWF load 3+ inch DC | 108 | 1000 | 65 | 20 | 0 | 0 |
| BS trees/sapl. densities | 95 | 54 | 97 | 3 | 0 | 0 |
| Ave. willow stem diameter | 71 | 67 | 44 | 114 | 0 | 0 |
| Willow densities | 411 | 300 | 217 | 1 | 0 | 0 |
| Tree canopy cover | 6 | 19 | 4 | 121 | 0 | 0 |
| Tall shrub canopy cover | 46 | 55 | 54 | 93 | 0 | 0 |
| Low shrub canopy cover | 22 | 55 | 23 | 43 | 0 | 0 |
| Feathermoss canopy cover | 0 | 600 | 18 | 5 | 0 | 0 |
| Liverwort canopy cover | Appeared | Appeared | Appeared | Appeared | 0 | 0 |
| | | | Three Year Post-Fire Values as a Percent of Prefire Values | | | |
| Needleleaf seed./sapl.[3] | 7 | 113 | 167 | 44 | — | — |
| Hardwood seed./sapl.[4] | 294 | 176 | 8,202 | 22,750 | — | — |
| | | | Prefire Down or Dead Woody Fuels in Tons per Acre | | | |
| Up to 3 inches Dia. Class | 1.13 | 1.13 | 1.63 | 1.40 | 2.02- 9.15 | 0 |
| Over 3 inches Dia. Class | .12 | 0.00 | 1.05 | 3.76 | 2.11-12.13 | 0 |
| Total | 1.24 | 1.13 | 2.68 | 5.16 | 4.13-21.28 | 0 |

[1]DDWF = down or dead woody fuel, DC = diameter class.

[2]Values greater than 100 show an increase, values less than 100 show a decrease, while values of 100 show no change from prefire values.

[3]White spruce and black spruce seedlings and saplings.

[4]Paper birch (*Betula papyrifera)* and quaking aspen (*Populus tremuloides*) seedlings and saplings.

Trees and tall shrubs were killed, producing new dead fuel. Perhaps a hotter, slower moving fire would have consumed more of the small diameter twigs that were later killed.

Objective 2—Kill 50 to 100 percent of the black spruce. Objective was achieved. Between 54 and 97 percent of the black spruce (*Picea mariana*) trees were killed (Table 1).

Objective 3—Kill 50 to 100 percent of the decadent willow. This objective was not achieved in the Tall Willow Scrub Types because they were too wet to burn. The objective was achieved in vegetation types where black spruce occurred. The average stem diameter decreased 40 to 70 percent. However, new shoots more than replaced those that were killed by the fire (Table 1). Either the fire behavior models used did not work for these tall shrub scrub types or the down dead woody fuels dry at rates different from those in the models. If the fuel, duff, and soil moistures had been tracked, perhaps the poor burn potential could have been predicted.

Objective 4—Penetrate one inch or more into the moss and lichen mat. If you include the duff layer as part of the moss/lichen mat, this objective was partially achieved. Patches, usually small depressions of 0.5 to 3 inches deep, were visually observed in all four of the vegetation types that burned. Moderately severe burns were recorded in the woodland types.

## Resource Objectives

Objective 1—Return a portion of the vegetation communities to an earlier seral stage to improve moose browse. This objective was achieved in all stands touched by fire. The canopy cover of the tree layer, the tall shrub layer, the low shrub layer and the feathermoss (*Hylocomium splendens* and *Pleurozium schreberi*) layer were considerably reduced after the fire (Table 1). The presence of the thalloid liverwort (*Marchantia polymorpha*) and the number of small diameter willow stems increased after the fire.

Objective 2—Maintain habitat diversity. Objective achieved. Habitat diversity was maintained or increased. Differences in burn severity or depth of heat penetration induced small-scale diversity. Unburned inclusions within the burn increased the diversity of the vegetation mosaic. On a larger scale, not all sites burned, so some of the original diversity remains.

Objective 3—Reduce hazardous fuel loadings. Objective not achieved. Fuel loads were not lowered in the black spruce stands and they were only partially lowered in the white spruce (*Picea glauca*) stands. The amount of small fuels was originally light (Table 1). When fire killed the black spruce, it generated more small fuels than it consumed. In the white spruce stands large fuels were reduced, but small fuels were slightly increased.

Objective 4—Rejuvenate decadent willow stands. This objective was not achieved because the decadent willow stands were too wet to burn.

Objective 5—Provide unburned inclusions of vegetation to improve escape cover. This objective was achieved. Unburned inclusions remained in all vegetation types that burned. Some of the unburned inclusions were small, and some were large. This would make a difference in their effectiveness as sources of cover, depending on the target species.

Objective 6—Convert some stands of needleleaf and needleleaf-hardwood forests to an earlier stage of hardwood regeneration. This objective was achieved. The number of hardwood seedlings and saplings increased much more than the number of needleleaf seedlings and saplings in all forest and woodland types (Table 1). However, the needleleaf species were not exterminated. Eventually, if fire does not recur, these stands will probably return to needleleaf or mixed needleleaf-hardwood forest or woodland types.

Objective 7—Treat 5,000 to 10,000 acres. This objective was not achieved; the fire perimeter included only 1,200 acres.

## Research Objectives

Objective 1—Document fire effects on mesic lowland plant communities. This objective was partially achieved, since four of the nine studied vegetation types were at least partially burned.

Objective 2—Document fire effects on mesic lowland small mammal populations. This objective was partially achieved. Burned habitats were created in four of the nine habitat types under study.

Objective 3—Document fire effects on the wetland habitats. This objective was not achieved because the areas adjacent to wetlands or lakes did not burn. The fire prescription considered the burning conditions necessary for burning wetland habitats and fuel types. However, not enough consideration was given at the time of the burn to earlier rains and high water and to the drying time needed for these areas to become burnable.

## CONCLUSIONS

Was the Buttes Gap Prescribed Burn a success? It depends upon your perspective. On the one hand, seven of the resource and fire objectives were met (five fully and two partially). On the other hand, four objectives were not met and the prescribed burn took four years to accomplish. In addition, only the upland research objectives were partially met; none of the wetland research objectives were met. This is the greatest shortcoming of the Buttes Gap Prescribed Burn. The many lessons learned were incorporated into the on-going prescribed burn program. Most importantly, the Buttes Gap Prescribed Burn is a good example that fire is not always the perfect tool.

# Effects of Habitat Diversity on Fire Regimes in El Malpais National Monument, New Mexico

Henri D. Grissino-Mayer
Thomas W. Swetnam

El Malpais National Monument, located south of Grants, New Mexico, encompasses a highly diverse landscape that provides a unique research opportunity for investigating the fire ecology of southwestern ponderosa pine (*Pinus ponderosa* Laws.) forests in habitats of varying size, isolation, and land-use history. These habitats consist of steep-sided cinder cones, low-lying shield volcanoes, highly weathered early-Pleistocene basalt flows, younger mid-Pleistocene and late-Holocene basalt flows, and isolated "islands" (kipukas) completely surrounded by lava (Lindsey 1951; Maxwell 1982, 1986; Laughlin and others 1993). This landscape heterogeneity suggests that fire ignition probabilities and spread are highly variable, depending on the physical and vegetative characteristics of the individual habitat. Hence, the development of a fire management policy is complicated, because no single fire regime characterizes the fire history of all habitats within the Monument.

In addition, all habitats have been disturbed by human activities to some degree within the last 100 years (Mangum 1990). Large-scale sheep herding began in the malpais area in the early 1880's soon after the subjugation of the Navajo and Apache Indian tribes. The community of San Rafael, adjacent to the Monument, became the center for sheep herding, with tens of thousands of sheep grazing within and adjacent to the Monument by 1885 (Bailey 1980; Mangum 1990). A thriving timber industry began in the early 1890's. Ponderosa pine forests within the Monument and in the Zuni Mountains to the north were heavily logged until the early 1950's (Bureau of Land Management 1981; Mangum 1990). Fire suppression most likely began in the area sometime after the Cibola National Forest was established in the Zuni Mountains in 1931. No change in the fire suppression policy is expected until new fire management plans, currently in development, are implemented.

The purpose of this research is to:

- Determine the history of fire occurrence over the past 300 to 600 years in various habitat types using dendroecological techniques.
- Investigate spatial differences in fire regimes between sites, and propose possible historical and ecological explanations for these differences.
- Investigate temporal differences in fire occurrence within sites and propose possible explanations for these differences.
- Suggest preliminary recommendations for implementing a fire management policy that considers the complexity of the landscape and the historical perspective of human land-use patterns.

## HABITAT TYPE SITE DESCRIPTIONS

Habitat type designations currently in use by the U.S. Department of Agriculture, Forest Service are usually based on the potential climax association that an area can support (Daubenmire and Daubenmire 1964; Alexander and others 1987). In the malpais area, geology is the dominant factor that influences vegetation characteristics and associations, because the different periods of volcanism in the area create unique habitats in different successional stages. For this reason, habitat type designations for this study are based on geologic characteristics, such as those used by Smathers and Mueller-Dombois (1974) for volcanic areas in Hawaii, rather than potential climax associations.

### Ponderosa Pine Forests on Cinder Cones and Shield Volcanoes

This habitat type consists of ponderosa pine forests located on the two types of volcanic vents in the malpais area. We collected samples at: Cerro Rendija, a highly eroded, low-lying shield volcano; Cerro Bandera East, located on a slightly eroded cinder cone; and Lost Woman, a cinder cone completely surrounded by the Twin Craters lava field (Laughlin and others 1993). All three vents are steep-sided and have well-developed soils that support ponderosa pine forests on their northern and northeastern flanks, and a pinyon-juniper forest on their southern and western sides (Lindsey 1951). All three sites are adjacent to surrounding grasslands with a long history of grazing (Mangum 1990). The ponderosa forests at these sites have been logged of many of their larger trees, and the numerous stumps contain well-preserved fire-scarred catfaces. Occasional dense thickets of young ponderosa pine occur on the slopes of these vents, perhaps as a result of fire suppression activities.

### Ponderosa Pine Forests on Ancient Basalt Flows

We collected samples at three sites that typify the open ponderosa pine forests and grasslands on ancient,

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highly-eroded basalts that surround the malpais: Cerro Bandera North, La Marchanita, and Candelaria. Soils at all three sites are more highly developed and deeper than soils on younger basalt flows, and support abundant grasses, herbaceous cover, and an open ponderosa pine forest. Extensive logging has left numerous stumps with well-preserved catfaces at all three sites. Intense grazing and fire suppression have probably occurred at all three sites because of their proximity to springs, major roadways, trails, and rail systems.

## Ponderosa Pine Forests on Younger Basalt Flows

We sampled one site that typifies the ponderosa pine forest habitats located on moderately-eroded basalt flows. The Hoya de Cibola volcano and its lava flow are considered geologically younger than most vents in the Zuni-Bandera lava field (Ander and others 1981; Maxwell 1986). The lava flow on which the samples were collected is predominantly pahoehoe lava that creates a broken topography with numerous fissures. Forest litter, which facilitates fire spread, tends to accumulate in these fissures. The lava flow supports a low-density, open ponderosa pine forest on shallow soil with patchy grass cover. This site is immediately adjacent to grasslands and may have been impacted by grazing, despite its broken topography. Fires have been suppressed in this area up to the present because of its easily accessible location (U.S. Department of the Interior, National Park Service). We found no evidence of logging at this site.

## Ponderosa Pine Forests on Isolated Kipukas

Kipukas are "islands" of original substrate material (sandstone, limestone, or older lava) that have been completely surrounded by relatively recent lava flows (Lindsey 1951). We collected samples from two isolated kipukas: Mesita Blanca, completely surrounded by the Hoya de Cibola lava flow; and Hidden Kipuka, located one km to the northeast of Mesita Blanca and bounded by the Hoya de Cibola flow to the west and by the Bandera Crater flow to the east. In this study, the fire histories from both kipukas will be combined because of their small size, similar land-use histories, and close proximity to each other. Both kipukas support an open ponderosa pine forest around their perimeter and a pinyon-juniper forest on the higher elevations. The kipukas support excellent grass cover, while shrub cover is negligible. Because of their inaccessibility, logging has not occurred at either site, and fire suppression has been minimal. While limited grazing may have occurred on these kipukas, the impact was probably minimal compared to surrounding areas.

# METHODS

At each site, we collected cross-sections from stumps, logs, and snags with evidence of repeated scarring by fire (catfaces). Small wedges were obtained from a few living trees at each site to determine the most recent fire years (Arno and Sneck 1977). Samples were fine-sanded and all fire scars were crossdated to their exact year of occurrence using dendrochronological techniques (Stokes and Smiley 1968; Swetnam and others 1985). We determined the intra-annual seasonality of fires by noting the position of the fire scar within the annual ring (Baisan and Swetnam 1990). Fire-scar positions and their seasonal designations include:

- Between previous year's latewood and current year's earlywood—dormant season fire (before May)
- Early portion of the earlywood (early May to mid-June)
- Middle portion of the earlywood (mid-June to mid-July)
- Late portion of the earlywood (mid-July to mid-August)
- Within the latewood (after mid-August).

Indirect evidence of fire occurrence (such as traumatic resin ducts) was also noted.

The period chosen for compilation and comparison of results among sites is 1600 to 1880. This period was chosen because sample depth drops to low levels before 1600; 1880 marks the beginning of extensive Anglo settlement and large-scale sheep grazing in the malpais area (Mangum 1990). To evaluate both the history of fire ignitions and fire spread, fire years were quantified by the number of samples scarred for that year. At least ten percent of the samples at each site must have been scarred in any given year for that fire year to be included in the analyses. This ten percent cutoff emphasizes only major, widespread fires while de-emphasizing the smaller "spot" fires. We quantified fire intervals for each site by calculating the maximum, the minimum, and the mean fire interval (Romme 1980) and its associated standard deviation and coefficient of variation for various percentage scarred classes. The coefficient of variation (standard deviation/mean) is used in this study as a measure of the homogeneity of fire frequency over time. For each site, a master fire chart was constructed that displayed the spatial and temporal aspects of fire occurrence (Dieterich 1980). We describe differences in these aspects between sites based on substrate parent material type, fuel types and amounts, and local topography and its effect upon fire history. Finally, the dominant season of fire occurrence for individual sites was obtained by compiling frequency distributions of the intra-annual positions of fire scars.

# RESULTS AND DISCUSSION

## Fire Intervals

Information on fire intervals at all nine sites in the four habitat types is summarized in Table 1. During the period 1600 to 1880, the ponderosa pine forests occupying the low-lying grasslands within and around the malpais had the shortest mean fire interval, ranging from 5.7 years at Cerro Bandera North to 9.0 years at the Candelaria site. The mean fire interval for forests on the steeper sided cinder cones and shield volcanoes is only slightly longer at 6.9 and 8.3 years for Cerro Bandera East and Cerro Rendija, respectively. The longer mean fire interval for the Lost Woman site (11.6 years) is perhaps due to the surrounding topography. Cerro Bandera and Cerro Rendija are surrounded by forests and grasslands on well-developed soil in relatively

**Table 1**—Summary of mean fire intervals (more than 10% of samples were scarred) found for four representative habitats in El Malpais National Monument, 1600 to 1880

| Habitat type site | Fire interval summary | | | | |
|---|---|---|---|---|---|
| | *Mean* | *Stan Dev** | *Coef Var** | *Min* | *Max* |
| Ancient Basalt Flows | | | | | |
| La Marchanita | 7.5 | 5.1 | 0.68 | 1 | 21 |
| Cerro Bandera North | 5.7 | 3.1 | 0.54 | 2 | 16 |
| Candelaria | 9.0 | 4.9 | 0.54 | 2 | 23 |
| Cinder Cones and Volcanoes | | | | | |
| Cerro Bandera East | 6.9 | 3.0 | 0.44 | 2 | 13 |
| Cerro Rendija | 8.3 | 5.4 | 0.65 | 2 | 25 |
| Lost Woman | 11.6 | 7.6 | 0.66 | 3 | 30 |
| Isolated Kipukas | | | | | |
| Mesita Blanca | 11.4 | 6.4 | 0.56 | 4 | 29 |
| Hidden Kipuka | 14.8 | 11.5 | 0.78 | 2 | 33 |
| Combined | 11.4 | 8.5 | 0.75 | 2 | 41 |
| Younger Basalt Flow | | | | | |
| Hoya de Cibola | 14.0 | 8.0 | 0.57 | 2 | 31 |

*Stan Dev = Standard Deviation; *Coef Var = Coefficient of Variation.

unbroken topography that may facilitate fire spread to the cinder cone. Lost Woman is surrounded by a younger lava flow in broken topography that may hinder fire spread to this site.

The longest mean fire interval values exist in the ponderosa forests at the kipuka sites (11.4 years), Lost Woman (11.6 years), and Hoya de Cibola (14 years). These relatively long intervals are probably due to the location and surrounding topography at each site. We expected fires to occur at the Hoya site with lower frequency because of the open, low-density ponderosa forest and patchy grass cover, and because greater time is needed to accumulate fuels, especially within the lava fissures. Because of the small size of the two kipukas, fire occurrence may predominantly spread from the surrounding lava flows and would therefore be dependent upon the same factors affecting fire ignition and spread at the Hoya de Cibola site. In addition, the synchrony of fire years at both Mesita Blanca and Hidden Kipuka indicates that the intervening Hoya de Cibola lava flow hinders fire spread only minimally across the lava surface.

An equal and perhaps more important aspect of fire regimes is the variability of intervals between fires. The coefficient of variation (CV) is used in this study to describe this variability because it combines both the mean and standard deviation into one statistic and allows comparisons between sample populations with different means (Barber 1988). The lower the coefficient of variation, the lower the variability of intervals about the mean fire interval and the more homogeneous the intervals are between fires. The site with the most homogeneous fire intervals is Cerro Bandera East (CV = 0.44) indicating little variability about the mean fire interval of 6.9 years. Conversely, the Lost Woman, La Marchanita, and kipuka sites have the highest variabilities about their respective mean fire interval. These three sites represent three different habitat types, suggesting that the level of heterogeneity of fire occurrence is not dependent on habitat type.

## Grazing Impacts

We expect intense widespread sheep grazing to have a greater effect on the occurrence of large, widespread fires because grazing removes grass cover that provides the finer fuels necessary for fire to spread to adjacent areas (Pearson 1923; Madany and West 1980; Savage and Swetnam 1990; Bahre 1991). Therefore, while we expect to see little change in fire occurrence after 1880, we do expect to see a decrease in widespread fires beginning around 1880.

Figure 1 displays the years in which at least 10% of samples were scarred at sites representative of the four major habitat types in the malpais, and therefore displays only the largest widespread fires. At the Cerro Bandera East, La Marchanita, and Hoya de Cibola sites, major widespread fires decrease dramatically after about 1880. Between 1600 and 1880, fire intervals for widespread fires were 7.2, 7.5, and 12.5 years for the La Marchanita, Cerro Bandera East, and Hoya de Cibola sites, respectively. Between 1880 and 1940, these intervals increase to 14.8 years for the Cerro Bandera East site, and 33.0 years for the Hoya de Cibola site. The La Marchanita site records only one major widespread fire during this period (in 1900). In contrast, the mean fire interval for the kipuka sites was 9.1 years from 1600 to 1880, and showed little change during the period 1880 to 1940 (11.8 years), indicating grazing had little or no impact in these relatively inaccessible areas. However, after about 1940, wide-spread fires become rare in all sites sampled in all habitat types, perhaps as a result of fire suppression.

## Seasonality of Fires

Combining all nine sites, the season of fire occurrence could be determined on 1,493 fire scars. As seen in Table 2, the seasonality of fires is spread evenly throughout the growing season. This result differs from results of other studies in which the dominant season of fire typically occurs during

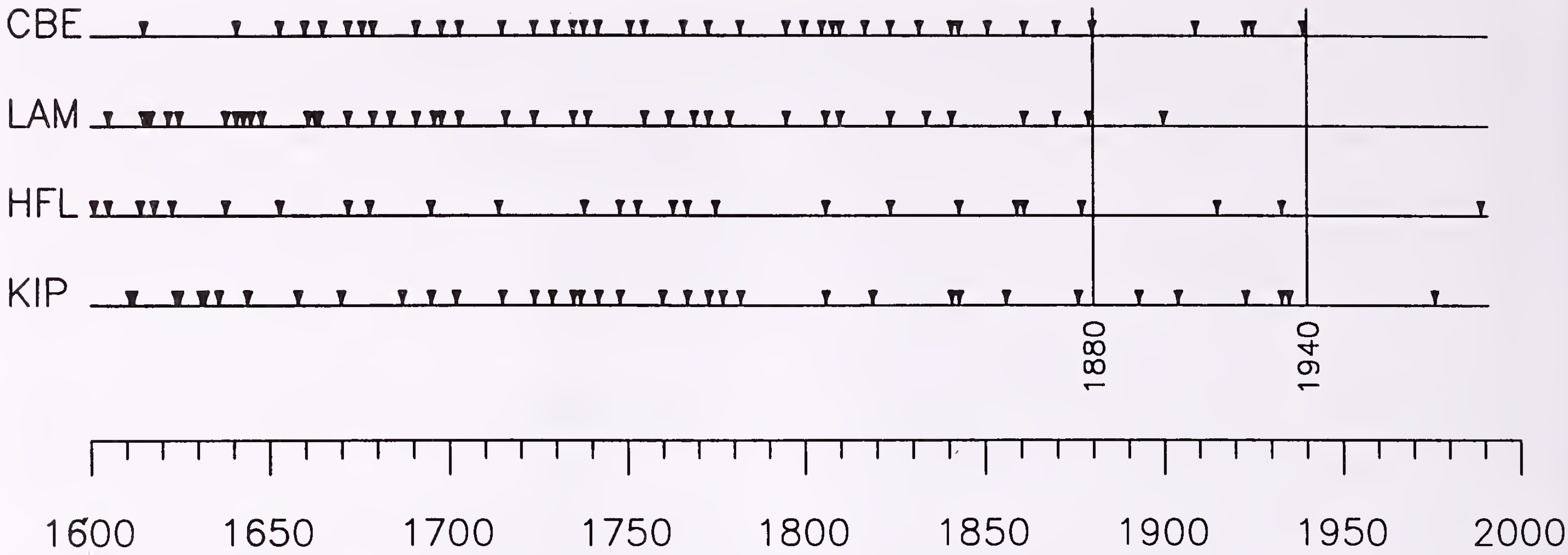


**Figure 1**—Composite fire chronologies for sites representative of the four major habitat types in the malpais area. Fire years are indicated by triangles. Only fires in which more than 10% of samples were scarred are plotted, indicating fires that were widespread. Study site abbreviations are: CBE (Cerro Bandera East), LAM (La Marchanita), HFL (Hoya de Cibola), and KIP (Kipuka sites).

**Table 2**—Summary of fire seasonality from all nine sites for 1,493 fire scars on which season could be determined

| Season | Total number | Percentage |
|---|---|---|
| Dormant Season | 331 | 22 |
| Early Growing Season | 376 | 25 |
| Middle Growing Season | 442 | 30 |
| Late Growing Season* | 344 | 23 |
| Total | 1,493 | 100 |

*Combines late earlywood scars and latewood scars.

the early or middle portion of the growing season, prior to the onset of summer monsoonal precipitation (Swetnam and others 1988; Baisan and Swetnam 1990; Grissino-Mayer and Swetnam 1992; Touchan and others, this proceedings). However, the dominant season of fire occurrence may be masked due to temporal changes in the seasonality of fire occurrence in the malpais area.

Figure 2 plots running percentages of early season fires (dormant season scars and scars in the early portion of the earlywood) versus late season fires (scars in the middle and late portions of the earlywood, and in the latewood) for all fire years from 1600 to 1991. Three dominant modes of fire seasonality are clearly displayed. From about 1630 to 1740, the majority of fires occurred during the early portion of the growing season. From about 1740 to 1840, fires predominantly occurred during the latter portion of the growing season. After about 1840, the fire season shifted back to the early portion of the growing season. Because seasonality of fire is probably coupled with Southwestern climate, these shifts may be due to shifts in regional-scale climate, in particular the seasonality and/or intensity of the bimodal precipitation regime in the Southwest. The temporal stability of the seasonality and intensity of Southwestern precipitation has already been questioned and investigated (Bryan 1940; Hastings and Turner 1965; Leopold 1951, 1976; Dean 1988). Future research should determine whether the temporal changes in fire seasonality are related to temporal changes in the precipitation regime of the Southwest. To help investigate this relationship, a 2,000 year tree-ring chronology is currently being developed to reconstruct climate for the malpais area.

## CONCLUSIONS AND RECOMMENDATIONS

We hypothesize that fire regimes in the malpais area are significantly influenced by the following factors and their interactions: degree of erosion of lava surfaces, subsequent soil development and supported vegetation, topography, size of area considered, and land-use history. These factors created highly variable pre-settlement fire regimes. The two habitats consisting of ponderosa pine

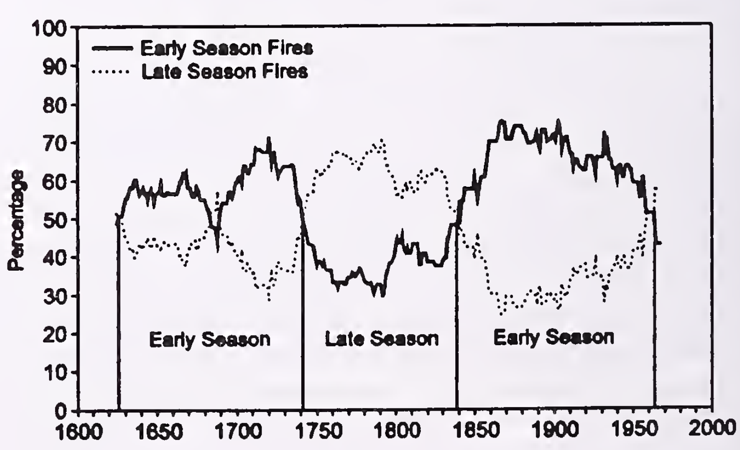


**Figure 2**—Running percentage plot of early season fires versus late season fires for successive 51-year overlapping periods, showing temporal shifts in the dominant season of fire occurrence in the malpais region.

forests on the steep-sided cinder cones and shield volcanoes and surrounding areas of the malpais on more ancient, weathered basalt flows had the highest occurrence of fire prior to 1880, with an average mean fire interval of about seven years. Ponderosa forests in the kipuka habitat and on moderately eroded basalt flows had the lowest occurrence of fire with mean fire intervals between 12 and 14 years. The coefficient of variation indicates that no specific habitat type had the most homogeneous occurrence of fire over time.

Widespread fires cease in accessible areas at about 1880 when intensive sheep grazing became widespread in the malpais area. This finding supports the hypothesis that grazing reduces the finer fuel classes and therefore reduces the ability of a habitat to carry fire. However, fires continued to occur into the 20th century at nearly all sites, but were not capable of spreading to adjacent areas. The two kipukas sampled for this study appear to have fire histories only minimally impacted by human disturbances. All fires recorded by fire scars abruptly cease at about 1940. This reduction in fires may reflect greater success in fire suppression. It may also be due to logging operations that significantly reduced the number of trees that could record fire occurrence with fire scars.

Combining all sites, we found no dominant season of fire occurrence; fires were distributed relatively evenly throughout the growing season. However, we did note that the seasonality of fires has shifted between a fire season dominated by early season fires (1600 to around 1740), to one dominated by late season fires (around 1740 to 1840), back to one dominated by early season fires (after about 1840).

To fully restore natural fire processes within El Malpais National Monument, it will be necessary to restore the present condition of forest stand structure and fuel loads to approximately the conditions that existed before human disturbance. To accomplish this, park personnel should consider the following alternatives:

- Domestic grazing should be reduced and ultimately excluded from the Monument to restore grass cover and fine fuels that would allow fire to spread
- Carefully implemented controlled burns should be conducted in small compartments to reduce the abnormally high levels of both live and dead fuels that have accumulated over time due to fire suppression and logging. Manual thinning of overstocked thickets of young ponderosa pine trees may be required prior to burning to reduce the hazard of fires "crowning" in the remaining overstory, old-growth trees
- Once forest and fuel conditions have been restored to approximately the natural conditions, naturally occurring fires should be suppressed within the Monument only when there is hazard to humans or private property.

These recommendations are solely the opinion of the authors and do not necessarily reflect the opinions of, or endorsement by, the National Park Service.

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# Displaying and Analyzing Seasonal Change in Vegetation Greenness

**Roberta A. Hartford**
**Robert E. Burgan**

The remote sensing community has developed an index, the Normalized Difference Vegetation Index (NDVI), that can be used to monitor vegetation greening and curing. The index is sensitive to the quantity of actively photosynthesizing biomass on the landscape. It has been used to monitor drought patterns globally and to rate fire danger in Australia (Paltridge and Barber 1988) and Spain (Lopez and others 1991). The index is incorporated into the Nebraska Forest Service fire danger rating system for rangelands (Westover and Sadowski 1987). The U.S. Department of Agriculture, Forest Service has accepted implementation of a system to track vegetation greenness derived from NDVI data. Normalized Difference Vegetation Index software and data will be hosted by the Weather Information Management System installed at the USDA National Computing Center at Kansas City. Land managers can retrieve data specific to their area, then use public domain software to display and analyze the images on their personal computers (PC).

Reflectance data in five spectral channels are collected by Advanced Very High Resolution Radiometers (AVHRR) on board the National Oceanic and Atmospheric Administration's polar orbiting weather satellites. Two daily satellite overpasses (one over the eastern United States and one over the West) collect data at a resolution of 1.1 km. Therefore, one picture element, or pixel, represents a square on the ground about 1 km or 0.6 mi per side. A number representing the amount of light reflected from each square kilometer of the earth's surface is recorded for each of the five channels. However, channel 1 (red, 0.58 to 0.68 microns) and channel 2 (near-infrared, 0.725 to 1.10 microns) are most useful for monitoring vegetation. They are used to calculate NDVI.

The NDVI is the difference between near-infrared (near IR) and visible red reflectance values normalized over total reflectance. That is,

$$\text{NDVI} = \frac{\text{Near IR (Channel 2)} - \text{Red (Channel 1)}}{\text{Near IR (Channel 2)} + \text{Red (Channel 1)}}$$

This equation produces numbers ranging from –1.0 to 1.0. Negative values generally represent clouds, snow, water, and other surfaces without vegetation. Vegetated areas are represented by positive values that increase as the quantity of green biomass increases. The value of 0.66 represents a fully irrigated vigorous crop or other fully green vegetation.

Observations free of interference are required to accurately assess reflectance from vegetation. Clouds, haze, or an increased reflectance path through the atmosphere, caused by the satellite passing far off nadir (when it has an oblique rather than an overhead view), can decrease reflectance values. The effects of interference are reduced by preparing composited maps made up of data from several day's observations. Each day's data are referenced to a common map projection, then the maximum value recorded for each pixel during a 2-week period is composited into a map. The EROS (Earth Resources Observation Systems) Data Center prepares these maps for the 48 conterminous States. Because vegetation changes may occur fairly rapidly, the maps are updated weekly by dropping the oldest week's data and adding the most recent week's. These NDVI data sets will be delivered weekly to the National Computing Center and to the Initial Attack Management System.

The NDVI values from pixels representing areas on the ground covered by grass, shrubs, or forest trend differently for each vegetation type. The highest values indicate complete or nearly complete coverage by green plants, while the low values indicate cured or sparse vegetation. These trends differ from one year to the next as plants respond to each year's unique weather. The NDVI values traced through a season also show elevational influences in the timing of greenup and the extent of plant growth.

Two types of greenness maps, visual and relative, were developed (Burgan and Hartford 1993) to help managers interpret NDVI data and can be calculated using a PC program. They are displayed on the computer monitor by Image Display and Analysis (IDA) software (Pfirman 1991). An intuitive color scheme has been assigned to data values. Sparsely vegetated or cured areas are colored red, brown, and yellow, while areas with live vegetation are colored in increasingly deep green tones. The visual greenness map is calculated by rescaling NDVI values (0.00 to 0.66) to a range of 0 to 100 percent, where 100 percent represents complete coverage by vigorous growing vegetation. This map represents vegetation in the way you would expect to see it if flying overhead. The relative greenness map relates each pixel to its own range of values as observed over the past 4 years (1989 to 1992) and expresses greenness as a percentage from 0 to 100 percent of each pixel's potential minimum to maximum range. Both maps provide useful information on vegetation condition.

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The IDA software can be used to analyze vegetation change. Split screen features display multiple images for comparing different composite periods or different years, and for viewing adjoining areas. Managers can "zoom" in on an image to observe a specific area and can display geographic location and numerical greenness values at the cursor location. Histograms can be prepared by using the IDA software to "stab" through an entire season of images at a specific location to determine the progress of greenup and curing or to compare the year's peak vegetation production with the site's potential. Difference maps calculated by the IDA software illustrate the change in greenness between composite periods.

The NDVI images, the software used to calculate visual and relative greenness maps, and the IDA software are available from the Weather Information Management System the USDA National Computing Center at Kansas City. The most current image and the past week's image can be retrieved. A self-study guide was developed to help managers learn to use the software to interpret vegetation condition (Hartford and Burgan 1993).

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# Greater Yellowstone Area Fire Growth, 1988 ✓

**Roberta A. Hartford**
**Carolyn A. Chase**
**Richard C. Rothermel**

Extensive fires burned within Yellowstone National Park and the surrounding National Forests during the summer of 1988. The intensive effort to map fire position and monitor fire weather for strategic and tactical planning provided an unparalleled opportunity for studying large fire behavior. A research effort was initiated soon after the fires were over to reconstruct the fire behavior and conditions that produced 3 months of large fire growth. Fire growth in the greater Yellowstone area from June 14 through October 1, 1988 has been digitized, reviewed, and corrected. Major fires included in the data set are the North Fork-Wolf Lake, Fan, Hellroaring, Storm Creek, Clover-Mist, Snake River Complex, Huck, and Mink Fires. Weekly maps illustrating daily growth were produced from this data set.

The fire record incorporates data from a variety of sources including infrared photography flights, satellite imagery, ground and aerial reconnaissance, command center intelligence, and the records and recollections of fire behavior observers. The GRASS Geographic Information System (GIS) was used to digitize daily fire perimeters from topographic maps and produce fire location files in both raster and vector formats. The fire position was analyzed and corrected relative to the digital burned area survey files. Dates specific to fire position were confirmed or corrected based on written chronological reports and interviews with fire observers.

The size of the fires and the amount of smoke produced prevented daily observation of all segments of the fires' perimeters. Late in the summer, fires often did not stop moving at the end of the day and continued burning substantial areas through the night. While considerable effort has been made to accurately present fire position by date, many potential sources of error remain; the data should not be considered as absolute truth or be considered for determining legal questions such as whether or when a particular feature was burned.

Fires do not burn vegetation in all areas completely, but leave unburned pockets and irregular perimeters, forming mosaics of burned and unburned areas. Satellite imagery was used to identify the final perimeter and burned areas that had not been mapped during the fires. Large unburned areas within the fires' perimeters were excluded when possible, but many small patches of unburned vegetation were not identified for exclusion.

The fire growth data base is available in electronic form from the National Park Service, P.O. Box 168, Yellowstone National Park, WY 82190. Further analysis of large fire growth is planned using an extensive ancillary data base including topography, pre-fire vegetation, fire severity, and weather along with the fire growth record.

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# The Importance of Intense Crown Fires to Some Bird Species in Rocky Mountain Coniferous Forests

**Richard L. Hutto**

I conducted point-count breeding bird surveys during 1989 and 1990 in 38 different sites that burned in 1988 in Montana and Wyoming. Nearly 90 species were recorded within sites that varied in size from 50 ha to more than 100,000 ha. By comparing my census results with those compiled from several hundred studies conducted in unburned forest types, I found that one species (Black-backed Woodpecker) appears to be nearly restricted to early post-fire conditions, where it forages on the numerous wood-boring beetle larvae available in the trees killed by the fire. Many other species (such as Hairy Woodpecker, Three-toed Woodpecker, Olive-sided Flycatcher, Clark's Nutcracker, Mountain Bluebird, Townsend's Solitaire, Cassin's Finch and Red Crossbill) are more abundant in early post-fire habitats than in any other forested habitat in the Northern Rockies. Most breeding birds also relied heavily on already existing snags (old-growth elements) for nesting purposes. The maintenance of viable populations of these bird species is likely to require maintenance of an intense crown-fire regime, especially because of the presence of standing dead timber. Unfortunately, the standing dead timber is routinely cut in "salvage" operations.

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# Fire History of Subalpine Forests at Fraser Experimental Forest, Colorado

**Laurie Stroh Huckaby**
**W. H. Moir**

Fire frequencies are largely unknown for the cold spruce-fir forests at high elevations in the Rocky Mountains. Dating prehistoric fires is complicated by the fact that most fires in such forests are stand-replacing crown fires which leave few, if any, scarred trees. Few studies have focused on this problem (Arno and Peterson 1983, Duncan and Stewart 1991, Hemstrom and Franklin 1982, Johnson and Fryer 1989, Lande 1979, Romme and Knight 1981) and most existing information is anecdotal. At present, there is no reliable method to date such fires, yet quantitative information on the fire histories of subalpine forests is necessary if we are to manage them in their pre-settlement state, as mandated for Wilderness Areas and Parks.

In this study, we tested the cohort analysis method as a way to date fire episodes in the absence of fire-scarred trees. The method approximates fire dates based on the ages of the oldest trees from cohorts in a stand, assuming that they established some time after a stand-replacing disturbance. However, these data are censored; the oldest trees of a cohort may already be dead or too rotten to sample (Fox 1989). Because tree establishment following fire may last many years, we are unlikely to be able to resolve individual fire events, but we should be able to resolve fire "episodes," or periods of disturbance, using this method.

We also investigated whether we could improve resolution of fire episodes by using stratified forest structure classes in conjunction with cohort ages (Lorimer 1985). We used tree rings to approximate fire dates in a few stands near burn edges, where release rings after a fire indicated trees which survived known historic fires.

Hemstrom and Franklin (1982) used the age structures in stands of seral tree species to reconstruct disturbance history in Mount Rainier National Park, where the disturbance regime is characterized by infrequent stand-replacing fires. They used ring counts in conjunction with age-class boundaries, mapped from aerial photographs and field work, to distinguish stands which had established in pulses of regeneration following fires, avalanches and volcanic mudflows. Fire was the most common and important disturbance, and a number of fire episodes were identified on the landscape, most of which corresponded to major droughts reconstructed for the area. They proposed a natural fire frequency of over 400 years, and concluded that fire suppression in this century had probably had little effect on the fire regime, but that fires such as had occurred there in the past might not be amenable to suppression.

Johnson and Fryer (1989) used age class distributions in lodgepole pine-Engelmann spruce forests to reconstruct recruitment and mortality patterns in the Canadian Rockies. They recognized both fire and understory regeneration cohorts, and noted that the post-fire cohorts of both species established in the first decade following fire, but had different establishment and survival patterns in subsequent years. They also noted that the long-term population dynamics of pine and spruce appear to be controlled by fire frequency.

## THE STUDY SITE

The Fraser Experimental Forest is located in the central Rocky Mountains of Colorado, approximately 150 miles northwest of Denver. Established in 1937, the experimental forest encompasses 94 square km of subalpine forest and alpine tundra; elevations range from 2,700 m to 3,940 m, and nearly a third of the area is above treeline. The climate is cool and humid, with long cold winters. Lodgepole pine (*Pinus contorta* var. *latifolia*) is the dominant tree at lower elevations and on dry upper slopes; Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) dominate at higher elevations and in cold air drainages. The north end of the forest was logged and burned early in this century (Troendle and others 1987). A wide variety of research has been conducted at the forest, including cutting methods experiments, water yield studies, seed dispersal and regeneration studies, wildlife use studies and meteorological monitoring. The experimental forest is a Biosphere Reserve in the Man And the Biosphere program and is administered by the Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, in Fort Collins, Colorado.

## METHODS

### Field Methods

**Randomly Sampled Plots**—In each of four cutting methods control plots, we cored 25 to 35 randomly selected trees at breast height to determine whether random sampling could capture the disturbance cohort structure of a stand. Three of these plots (B, C, and D) were old-growth lodgepole pine; the fourth was an old-growth spruce-fir stand in which lodgepole pine was seral.

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**Selectively Sampled Plots**—In each of 70 plots throughout the forest, most of them 375 m² in area, we cored what appeared to be the oldest trees. Plots were selected to be representative of the different forest communities at the experimental forest. For this reason, the plots were subjectively located in different habitats and not located randomly or along transects. More plots are concentrated in the north end of the forest due in part to accessibility and to the variety of habitats at lower elevations. Plots were not permanently marked.

Tree density and structure were measured by counting all established trees by d.b.h. classes and species within each plot. Most of the trees cored were lodgepole pines; Engelmann spruce was sampled when pine was not available. Spruce lives considerably longer than lodgepole pine, and though usually shade tolerant, will invade or release in fire-created openings. Limber pine (*Pinus flexilis*), which may be seral at high elevations, does not occur at the forest.

A minimum of three selected trees were cored at breast height in each plot. Lodgepole pines were selected for coring based on the following somewhat subjective characteristics for appraising oldest trees: dominance in the canopy; smooth, yellowish bark, large branches (alive or dead) low on the trunk; large size (not always reliable); small live crown ratio; and the presence of mistletoe, dead tops or other damage resulting from a long, risk-filled life. Spruces were selected based on similar characteristics, including the evidence of deformity early in life resulting from growing in the open at high elevations; the presence of layered offspring and/or a layered origin; smooth, rust-colored bark; large diameter; and damage such as lightning scars. Large size does not necessarily correlate with old age in high-elevation forests, so this criterion was given less weight in selection of trees for sampling.

For each tree, we recorded species, diameter at breast height, elevation, slope, and aspect; we took notes on its condition. Sample locations were recorded on U.S. Geological Survey quadrangle maps. Cores were mounted and sanded; the rings were counted under magnification. Ages at breast height were corrected for pith age when the core missed the center by using concentric circles on paper to estimate the distance to the pith from the curvature of the rings, then using the mean width of the five innermost rings to estimate the number of rings between the innermost ring and the pith. Variations in ring widths from sensitive trees were noted for further analysis.

## Analysis

Our analysis was conducted in three parts: a study of randomly sampled tree ages from the control plots; an analysis of selectively sampled tree ages based on forest structure classes; and a geographic interpretation based on aerial photographs and the spatial distribution of our plots.

**Random Samples**—For the randomly sampled ages in each old-growth control plot, the age distributions were compared between all plot pairs using the Kolmogorov-Smirnov two-tailed test.

**Selective Samples**—In the 70 selectively sampled plots, we devised 11 forest structure type classes based on the densities of established trees by d.b.h. size class and species. These structure classes, described in Table 1, included old forests succeeding to spruce-fir in three environments: mesic, cold, warm; old forests succeeding to lodgepole pine; young spruce-fir forests; young pine forests; mixed-aged stands; stands dominated by aspen (*Populus tremuloides*); and two special types, an avalanche track and a high-elevation burn meadow.

We used MRPP analysis of variance methods (Mielke 1984) to test whether the ages of trees were different among pairs of structural types by combining individual trees among plots within vegetative structure classes and comparing maximum ages among classes. To distinguish individual classes from one another, pairs of classes were analyzed in the same manner, with a Bonferroni adjustment (Miller 1981) applied to estimated significance levels to maintain Type I error across the group of paired analyses.

**Geographic Interpretation**—We constructed a map of the forest structure types based on interpretation of aerial photographs of Fraser (Fig. 1). Some of the map units in Figure 1 were combined, renamed or not used in the final analysis, which was done after the photograph was produced, but the map shows the distribution of the important forest types. Many of the map units were confirmed by measurements in our plots and by other reconnaissance; some, especially at high elevations, were determined from the photos alone. We used the age data from our plots and the structure types from the aerial photographs to construct a map layer of 50-year age classes on a topographic map (Fig. 2).

Some preliminary work was done with tree-ring analysis. Obvious release patterns in some of the cores were compared with known disturbance dates and with cohort ages in the plots.

# RESULTS AND DISCUSSION

## Randomly Sampled Plots

Analysis of the randomly sampled plots revealed that random sampling showed the skewed distribution of tree ages discussed by Lorimer (1985), but chances of sampling the oldest trees in a cohort by random selection are very small, particularly if the stand is old and few of the oldest cohorts are available. The random sampling method is inefficient for sampling the oldest trees.

Figure 3 compares the age distributions in the three lodgepole pine control plots. These 2-ha plots are within 0.5 km of one another, on slightly different slopes and aspects. While their maximum stand ages all fall into the 250 to 300-year age class and all are in the same structure class (cold), the Kolmogorov-Smirnov test shows their age distributions to be significantly different at the 1% level; plots B and C differ at the 5% level. Based on their adjacent locations in the landscape, one would expect that all of these stands were initiated by the same fire. Small differences in microsite conditions apparently altered the rate of tree establishment enough that the age distributions obtained by random sampling suggest they could be different cohorts, though this seems unlikely from a biological point of view. The spruce-fir control plot several kilometers away in another watershed had a stand age similar

**Table 1**—Forest structure summarized by type for the Fraser Experimental Forest. Species abbreviations are: ABLA means subalpine fir, PICO means lodgepole pine, PIEN means Englemann spruce, and POTR means quaking aspen.

| Description | Mean max age | Max age range | Species | Mean trees per hectare for structure class by 10-cm size class at bh | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | <bh | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | >50 |
| | | | | | cm | | | | | |
| Aspen (Dal) | 99 | 69-115 | ABLA | 619 | 42 | 26 | 20 | 0 | 0 | 0 |
| 6 plots | | | PICO | 18 | 55 | 100 | 42 | 0 | 0 | 0 |
| | | | PIEN | 164 | 115 | 106 | 33 | 0 | 0 | 0 |
| | | | POTR | 285 | 757 | 1229 | 171 | 30 | 19 | 0 |
| Spruce-fir old growth (So) | 301 | 200-431 | ABLA | 1791 | 546 | 261 | 83 | 18 | 0 | 0 |
| Mesic environment | | | PICO | 72 | 46 | 34 | 64 | 53 | 11 | 4 |
| 17 plots | | | PIEN | 543 | 330 | 131 | 95 | 83 | 42 | 20 |
| | | | POTR | 8 | 5 | 3 | 2 | 0 | 0 | 0 |
| Spruce-fir old growth (So+) | 389 | 172-630 | ABLA | 1553 | 604 | 187 | 76 | 22 | 7 | 0 |
| Cold environment | | | PICO | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 plots | | | PIEN | 1334 | 576 | 201 | 138 | 146 | 102 | 55 |
| | | | POTR | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spruce-fir old growth (So–) | 294 | 255-319 | ABLA | 483 | 300 | 61 | 0 | 0 | 0 | 0 |
| Warm, dry environment | | | PICO | 25 | 31 | 209 | 253 | 138 | 41 | 0 |
| 5 plots | | | PIEN | 175 | 98 | 79 | 32 | 22 | 0 | 0 |
| | | | POTR | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spruce-fir pole stands (Sp) | 150 | 117-172 | ABLA | 725 | 620 | 243 | 52 | 0 | 0 | 0 |
| 4 plots | | | PICO | 7 | 151 | 406 | 101 | 30 | 10 | 0 |
| | | | PIEN | 453 | 392 | 61 | 20 | 10 | 7 | 10 |
| | | | POTR | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spruce-fir (Spv) | 123 | | ABLA | 238 | 437 | 79 | 0 | 0 | 0 | 0 |
| Avalanche track | | | PICO | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 plot | | | PIEN | 556 | 1151 | 675 | 278 | 0 | 0 | 0 |
| | | | POTR | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lodgepole pine old growth (Lo) | 299 | 254-332 | ABLA | 262 | 70 | 21 | 10 | 10 | 0 | 0 |
| 8 plots | | | PICO | 645 | 403 | 171 | 228 | 129 | 44 | 0 |
| | | | PIEN | 30 | 6 | 7 | 0 | 4 | 0 | 0 |
| | | | POTR | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lodgepole pine (Lpo) | 263 | 247-281 | ABLA | 159 | 30 | 51 | 0 | 0 | 0 | 0 |
| 2-aged pole stands | | | PICO | 632 | 931 | 514 | 158 | 33 | 9 | 0 |
| 3 plots | | | PIEN | 58 | 9 | 20 | 9 | 0 | 0 | 0 |
| | | | POTR | 9 | 19 | 0 | 0 | 0 | 0 | 0 |
| Lodgepole pine (Lyp) | 136 | 65-180 | ABLA | 646 | 293 | 32 | 11 | 21 | 0 | 0 |
| Young pole stands | | | PICO | 378 | 659 | 621 | 289 | 33 | 0 | 0 |
| 5 plots | | | PIEN | 256 | 240 | 11 | 11 | 16 | 5 | 5 |
| | | | POTR | 536 | 227 | 43 | 0 | 0 | 0 | 0 |
| Lodgepole pine (Lys) | 64 | 60-67 | ABLA | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| invaded meadows | | | PICO | 806 | 1264 | 115 | 35 | 71 | 0 | 0 |
| 2 plots | | | PIEN | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | POTR | 290 | 66 | 0 | 0 | 0 | 0 | 0 |
| Spruce-fir (Ohs) | 144 | 74-214 | ABLA | 1080 | 285 | 27 | 0 | 0 | 0 | 0 |
| Old high-elevation burn | | | PICO | 184 | 17 | 66 | 8 | 0 | 0 | 0 |
| 3 plots | | | PIEN | 2169 | 732 | 400 | 161 | 54 | 0 | 0 |
| | | | POTR | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

to the lodgepole pine plots and could have established after the same fire if it was a large crown fire typical of this system, but its overall age distribution was significantly different from all of the other plots. Therefore, we remain unsure whether the same or different fires initiated them.

## Selectively Sampled Plots

Selectively sampling for the oldest trees in the stand seemed more likely to capture the earliest regeneration following a stand-replacing fire, especially in lodgepole pine. However, there are certain dangers in relying on


**Figure 1**—Forest stand types as interpreted from air photos and confirmed in most cases by reconnaissance.

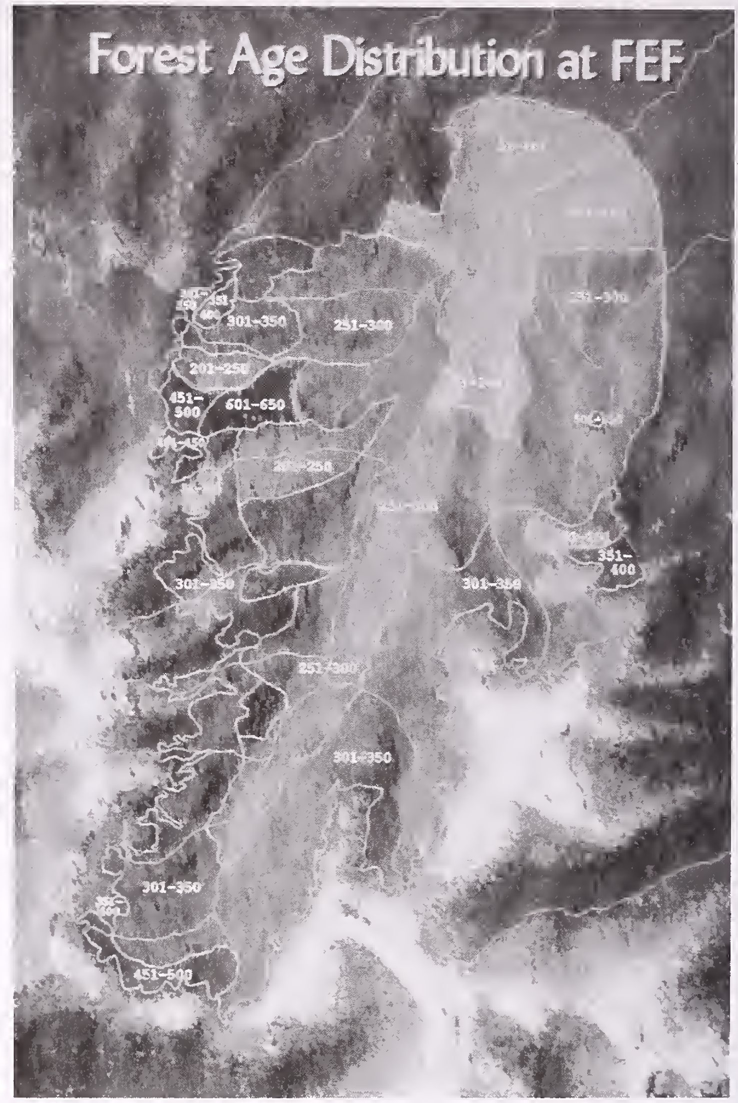


**Figure 2**—Distribution of oldest cohort ages based on age sampling and forest stand types determined from air photos and field reconnaissance. The 250 to 300-year age class closely coincides with the distribution of lodgepole pine (Alexander and others 1985).

this method to actually date disturbances. Establishment following fire is a long process in the subalpine forest, and though trees may begin to establish in the first years following a fire, mortality is high and canopy closure may not occur for another 50 years. It is always possible that the oldest members of a cohort are unavailable for sampling due to mortality or rot. Where two or more fires occurred in an area, it is possible that the oldest fire cohort is completely gone and the measurable cohort is actually the one which filled in upon the demise of the first cohort. Lodgepole pine is a short-lived species (300 to 350 years) and is unlikely to preserve records of more than one fire in a long fire regime like the one at Fraser. Disturbances which overlap one another in space within a short period of time, such as a fire followed by a massive blowdown along burn edges, or a light burn followed by a more intense fire shortly afterward, might cause deceptively uniform age cohorts. The cohort method cannot accurately date disturbances to a year, as fire scars can; in fact, we were not able to discern cohorts less than 100 years apart.

Forest structure data combined with tree ages helped to discern the existence of different age cohorts. While there is no clear size-age relationship in trees at high elevations, the size and species composition of stands is indicative of different stages of stand development. Structure data gives clues about multiple cohorts and succession, and the structure classes we constructed were reflective of stand ages. Table 2 shows how the stand structure classes compared using MRPP analysis of variance. Maximum age differed significantly among the vegetative structure classes ($p < 0.0001$). All of the old-growth types were similar in age except the spruce in cold environments, which was considerably older. This type is found in wet areas and near treeline, where we expected disturbance

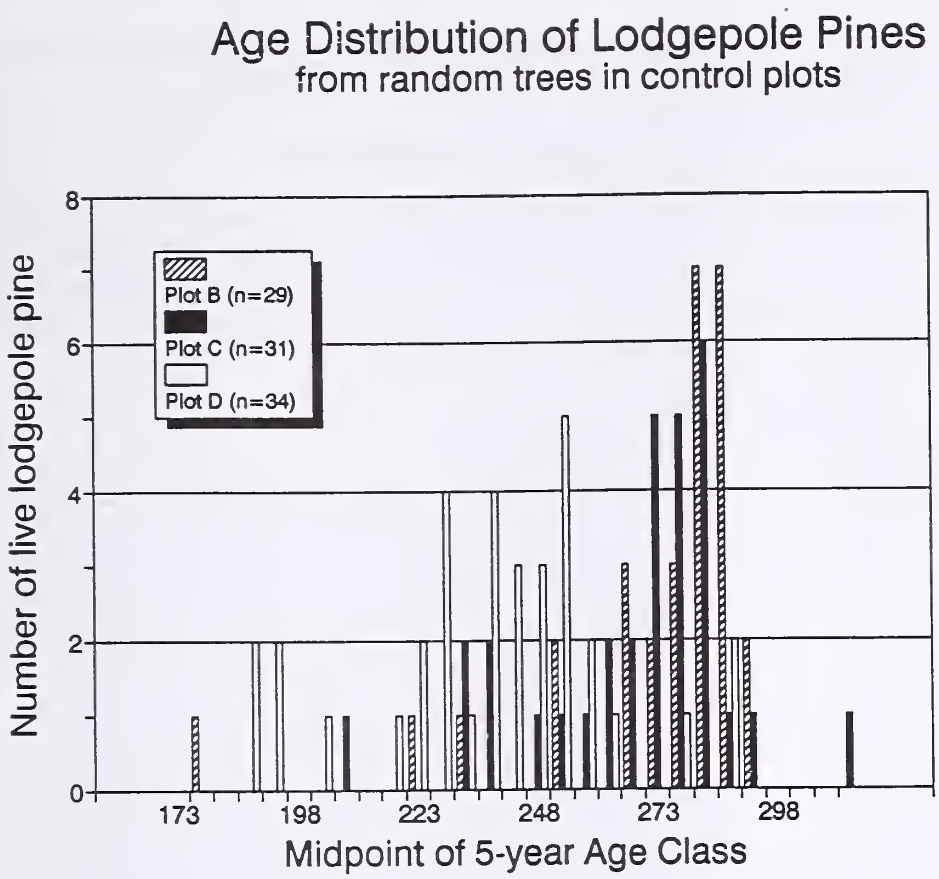


**Figure 3**—Age distributions of trees randomly sampled in three lodgepole pine plots. The distributions of all plots are skewed to the right.

to be less frequent. The pole stands were significantly different in age from the old-growth stands; the spruce pole stands were closer in age to the two-aged pine stands than to the younger pine pole stands, probably due to the fact that the spruce grows more slowly.

## Geographic Interpretation

When the age and structure data were analyzed spatially (Figs. 1 and 2), patterns emerged on the landscape. We discerned two distinct cohorts among our plots. The 251 to 300-year age class, with lodgepole pine seral or self-perpetuating on dry slopes, occupies a large area in the valley up to about 3,000 m. The distribution of this age class coincides closely with the delineation of stands dominated by lodgepole pine on the map constructed by Alexander and others (1985). The other cohort, a 51 to 100-year age class, coincides with a known historic fire in the north end of the forest early in this century. Most of the trees in this age class are about 80 years old.

## Additional Observations

Multiple-aged stands indicated possible burn edges. We found evidence of another cohort 101 to 150 years old in the same area as the 51 to 100-year cohort, but it seems likely that the historic 1907 fire overlapped most of this cohort, making it impossible to map. Tree-ring release dates from plots on the edges of the 1907 burn confirm both cohorts. Hints of a 400-year-old cohort were found at

**Table 2**—Bonferroni-adjusted significance levels for comparisons between paired structure classes are given in the upper portion of the table. Mean maximum age per class is given on the diagonal of the table. ** indicates significance level is less than 0.01

| | Lys | Dal | Spv | Lyp | Ohs | Sp | Lpo | So | So- | Lo | So+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lys | 64 | ** | ** | | .08 | ** | ** | ** | ** | ** | ** |
| Dal | | 99 | | | | ** | ** | ** | ** | ** | ** |
| Spv | | | 123 | | | | | ** | ** | ** | ** |
| Lyp | | | | 136 | | .01 | ** | ** | ** | ** | ** |
| Ohs | | | | | 144 | | | ** | ** | ** | ** |
| Sp | | | | | | 150 | | ** | ** | ** | ** |
| Lpo | | | | | | | 263 | ** | ** | ** | ** |
| So | | | | | | | | 301 | | | ** |
| So- | | | | | | | | | 294 | | .02 |
| Lo | | | | | | | | | | 299 | |
| So+ | | | | | | | | | | | 389 |

about 3,000 m the central part of the valley; a few very old lodgepole pines were found at the upper edge of the 251 to 300-year age class. This cohort may have been largely overlapped by a late 17th-century fire.

Preliminary sampling in a fire-created meadow above 3,000 m yielded confusing results. Many of the spruce which are filling in the meadow were badly deformed early in life and are difficult to age. We are planning more study of this site to try to understand regeneration patterns in high-elevation burns. Stands dominated by spruce at higher elevations had widely varying age distributions without discernable cohorts, indicating that they had not been disturbed for many centuries. Two pockets of 600-year-old trees widely distant from one another may mark the last widespread disturbance above 3,000 m. Aplet and others (1988) discuss the dynamics of high-elevation spruce forests without disturbance.

Tree-ring analysis may also help discern disturbance dates. Large fires often coincide with drought periods (Hemstrom and Franklin 1982) which could be detected by dendrochronology. Release dates along burn edges could help date fire episodes, and subtle fire scars mostly healed over, which do not show up in cores, may become apparent in wedges from living and dead trees. Death dates of fallen logs might also help support fire dates, though logs may have been consumed in intense fires. We are pursuing this method further.

## CONCLUSIONS

Cohort analysis alone seems to be of limited use. Random selection of trees is inefficient for sampling the oldest trees. Subjective selection is fraught with difficulties, including the possible unavailability of the oldest trees due to rot or mortality, the short lifespan of lodgepole pine, the wide variability of timing in tree establishment and growth, and the probability of spatially overlapping disturbances. We were unable to resolve cohorts less than about 100 years apart.

Cohort analysis in conjunction with forest structure types strengthens the identification of separate cohorts. Cohort analysis combined with forest structure types and tree-ring analysis may give the best resolution of old fires and other disturbances. We are planning further study in this area.

Multiple-aged stands can be good evidence of multiple disturbances, but surviving trees are rare except along burn edges. The chances of a tree surviving and preserving records of more than one fire are very small, and multiple-aged stands may arise as the result of disturbances other than fire.

Our data suggest at least two fire cohorts at Fraser. The most recent, on the north end of the forest, is the result of a known historic fire. The second discernible fire cohort is in the 251 to 300-year age class, and extends southward along the valley to about 3,000 m elevation. This fire or fires was large in extent and resulted in a widespread population of lodgepole pine. There is also a possible third low-elevation fire around 151 to 200 years ago, but its resolution by our techniques is weak. Trees at higher elevations were generally much older and fire-initiated cohorts were less discernible.

## ACKNOWLEDGMENTS

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# Underburning to Reduce Fire Hazard in the Southern Boreal Transition Forest of Voyageurs National Park, Minnesota: Preliminary Results

Stephen G. Jakala

Fire effects from management-ignited prescribed burns in natural communities within the boreal forest and Great Lakes-St. Lawrence transitional region were originally conducted and documented by the USDA Forest Service in the early 1960's (Buckman, 1964; Heinselman, 1992). Since that time, operational burns in this region have been conducted on a limited basis, and for the most part only in pine plantations, with little documentation of fire effects.

In 1989, Voyageurs National Park's Wildland Fire Management Plan became the first National Park Service fire management plan to be reinstated for implementation after the moratorium following the 1988 Yellowstone fires. This Wildland Fire Management Plan divides the Park into three fire management units. The Fire Suppression Unit provides for intensive protection of human life and property within the Park's developed zones. This unit also allows the use of mechanized equipment and management-ignited prescribed burns to reduce the amount of hazardous fuels. The Prescribed Natural Fire Unit is designed to allow lightning-caused fires to burn within a predetermined prescription. The Conditional Fire Unit balances the protection of life and property within and beyond the park boundary and restoring and perpetuating fire-dependent communities through the use of management-ignited prescribed burns and prescribed natural fires.

Since 1989, approximately 1,000 acres within the Park have been treated with management-ignited prescribed fire for hazard fuel reduction. All burns have had fire effects documented.

## METHODS

Management-ignited prescribed burns are monitored using guidelines from the National Park Service Western Region Fire Monitoring Handbook. Five vegetation types have been identified for fire effects monitoring; red pine (*Pinus resinosa*), eastern white pine (*Pinus strobus*), jack pine (*Pinus banksiana*), aspen/paper birch (*Populus tremuloides / Betula papyrifera*), and fir/spruce/birch (*Abies balsamea / Picea glauca / Betula papyrifera*). Fire monitoring plots are located in each representative vegetation type within designated burn units. Fuel loadings, overstory tree data and vegetation cover are determined on each 20- by 50-meter, 0.1-hectare (65.6 by 164 ft, 0.25 acre) plot prior to burning. Pole-size tree data is determined on a 10- by 25-meter, 0.25-hectare (32.8 by 82 ft, 0.06 acre) plot. Seedling/sapling data is determined on a 5- by 10-meter, 0.005-hectare (16.4 by 32.8 ft, 0.01 acre) plot. During the actual plot ignition, fire behavior observations are made on site. Immediately after the burn, and at 1-, 2-, 5-, and 10-year intervals, post-burn fuel loadings and long-term fire effects on vegetation are measured on the plot.

The Park uses both the National Fire Danger Rating System (NFDRS) and the Canadian Fire Weather Index (FWI) to monitor day-to-day burning conditions.

## DISCUSSION

The following observations are from two management-ignited prescribed burns conducted in red pine and white pine monitoring types within the past two years. Pre-burn and post-burn fuel loading and vegetation descriptions are contained in Table 1. The conditions during the two burns are summarized in Table 2.

## FIRE BEHAVIOR OBSERVATIONS

### Mukooda

A frontal system had moved into the area causing overcast skies with rain predicted for the following day. With anticipated backing fire rates-of-spread (ROS) of less than 33 ft/hr, strip head fires were used with ignitors approximately 66 ft apart. Observed head fire rate of spread was estimated at 132 ft/hr. Intense torching occurred in the balsam fir seedling/saplings and pole trees.

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Stephen G. Jakala is Fire Management Officer, Voyageurs National Park, International Falls, MN.

**Table 1**—Pre- and post-burn fuel loading and vegetation in the Mukooda and Blind Ash Bay prescribed burns, Voyageurs National Park

| | Mukooda | | | Blind Ash Bay | | |
|---|---|---|---|---|---|---|
| | Pre-burn | Post-burn | Reduction | Pre-burn | Post-burn | Reduction |
| | - - - - -*Tons/acre* - - - - | | *Percent* | - - - -*Tons/acre* - - - - | | *Percent* |
| | | | **Fuel loading** | | | |
| Size Class | | | | | | |
| 0.0-.25" | 0.3 | 0.0 | 100 | 0.2 | 0.1 | 50 |
| .26-1.0" | 1.4 | 0.4 | 71 | 1.2 | 0.8 | 33 |
| 1.1-3.0" | 0.4 | 0.0 | 100 | 2.1 | 1.2 | 43 |
| 3.1" + R | 9.9 | 6.7 | 32 | 3.0 | 3.0 | 0 |
| 3.1" + S | 7.6 | 6.1 | 20 | 5.7 | 1.6 | 72 |
| Total | 19.6 | 13.2 | 33 | 12.2 | 6.7 | 45 |
| Avg. Litter Depth | 1.4" | 0.3" | 81 | 1.0" | 0.6" | 40 |
| Avg. Duff Depth | 1.1" | 1.1" | 0 | 1.1" | 1.0" | 10 |
| | | | **Understory vegetation** | | | |
| | - - - - -*Tons/acre* - - - - | | *Percent* | - - - -*Tons/acre* - - - - | | *Percent* |
| Pole Tree Density | | | | | | |
| Balsam Fir | 371 | 0 | 100 | 1829 | 0 | 100 |
| White Spruce | 48 | 0 | 100 | 16 | 0 | 100 |
| Red Pine | 0 | 0 | — | 32 | 0 | 100 |
| Paper Birch | 16 | 0 | 100 | 0 | — | — |
| Total | 435 | 0 | 100 | 1877 | 0 | 100 |
| Seedling Tree Density | | | | | | |
| Balsam Fir | 1700 | 0 | 100 | 2344 | 0 | 100 |
| White Pine | 324 | 0 | 100 | 4777 | 0 | 100 |
| White Spruce | 0 | 0 | — | 161 | 0 | 100 |
| Red Maple | 1457 | 0 | 100 | 0 | — | — |
| Total | 3481 | 0 | 100 | 7282 | 0 | 100 |
| | | | **Overstory vegetation** | | | |
| | - - - - -*Tons/acre* - - - - | | *Percent* | - - - -*Tons/acre* - - - - | | *Percent* |
| Tree Density | | | | | | |
| Red Pine | 40 | 40 | 0 | 154 | 154 | 0 |
| White Pine | 48 | 44 | 8 | 105 | 105 | 0 |
| Jack Pine | 0 | 0 | 0 | 16 | 12 | 25 |
| Balsam Fir | 24 | 20 | 17 | 4 | 4 | 0 |
| White Spruce | 12 | 12 | 0 | 16 | 16 | 0 |
| Paper Birch | 4 | 0 | 100 | 4 | 0 | 100 |
| Total | 128 | 116 | 9 | 299 | 291 | 3 |

## Blind Ash Bay

High winds (above 20 mph) throughout the day delayed ignition until 6:30 p.m. Backing fires were used with measured rates of spread at 0.5 ft/min. Flame lengths were observed to be less than 1 ft. Moderate torching of the balsam fir seedling/saplings and pole trees occurred, especially in concentrated balsam fir blowdowns. The fire continued to back downhill until the following morning. The effects of the burns are summarized in Table 3.

## CONCLUSIONS

- Exclusion of fire from red and white pine stands in Voyageurs National Park has allowed significant concentrations of conifer seedlings, saplings, and pole timber to become established in the understory.
- The total fuel hazard problem in red and white pine stands consists of litter, dead woody fuels, and the cumulative ladder effect of understory conifer seedling/saplings and pole-size trees.
- Even low-intensity surface fires burning through red and white pine stands with an established conifer understory can cause significant canopy scorch and mortality in overstory trees.
- The amount and severity of overstory tree scorching may be significant even when relative humidities are higher than 45%.

**Table 2**—Conditions of the Mukooda and Blind Ash Bay burn units, Voyageurs National park. The burn day fire indices are for the National Fire Danger Rating System (NFDRS) and the Canadian Fire Weather Index (FWI)

| | Burn unit | |
|---|---|---|
| | Mukooda | Blind Ash Bay |
| Vegetation type and white pine | Old growth red pine | Mixed red and white |
| Age class | Multi-age classes Oldest age class 300 + yrs | 66 yrs |
| Past fire history | 3 low intensity fires in past 300 yrs. Last fire 70-80 yrs ago | Stand establishment in 1926 |
| Burn date | May 21, 1991 | May 29, 1992 |
| Burn day conditions | | |
| Litter fuel moisture | 10.5-14.9% | 11.9-13.1% |
| Duff fuel moisture | Unknown | 71.3% |
| 10-hour fuel moisture | 10% | 10.3% |
| Temperature | 72-78 °F | 72-74 °F |
| Relative humidity | 46-50% | 27-32% |
| Wind (midflame) | South 1-2 mph | South 1-2 mph |
| Sky conditions | Overcast | Clear |
| Burn day fire indices | | |
| NFDRS | | |
| Burning Index (BI) | 33 | 46 |
| Ignition Component (IC) | 11 | 33 |
| Spread Component (SC) | 6 | 11 |
| Energy Release Component (ERC) | 31 | 32 |
| FWI | | |
| Fine Fuel Moisture Code (FFMC) | 89 | 92 |
| Duff Moisture Code (DMC) | 38 | 24 |
| Drought Code (DC) | 84 | 98 |
| Initial Spread Index (ISI) | 8 | 15 |
| Buildup Index (BUI) | 38 | 30 |

**Table 3**—Fire effects from the two prescribed burns in Voyageurs National Park

| | Burn unit | |
|---|---|---|
| | Mukooda | Blind Ash Bay |
| Overstory tree bole char | | |
| Average | 9 ft | 7 ft |
| Range | 0-25 ft | 0-40 ft |
| Overstory trees with crown scorch | 91% | 13% |
| Crown scorch height | | |
| Average | 56 ft | 51 ft |
| Range | 40-85 ft | 20-70 ft |
| Crown scorch height (predicted) | 3 ft | 1 ft |
| Crown scorch percent | | |
| Average | 55% | 62% |
| Range | 10-100% | 10-100% |
| Crown scorch percent (predicted) | 0% | 0% |
| Overstory tree mortality 1 year post-burn | 22% | 14% |

## ACKNOWLEDGMENT

James Benedict, former Resource Management Specialist at Voyageurs National Park, authored Voyageurs' Wildland Fire Management Plan.

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# FOFEM: A First Order Fire Effects Model

**Robert E. Keane**
**Elizabeth D. Reinhardt**
**James K. Brown**

First order fire effects result directly from the combustion process. These effects include duff and woody fuel consumption, fire-caused tree mortality, smoke production, and soil heating. Managers need to predict first order fire effects for prescribed fires or wildfires to skillfully develop fire prescriptions and evaluate the impacts of wildfires. Knowledge of first order fire effects provides a quantitative means of planning and evaluating resource management activities. It also forms the basis for predicting secondary fire effects such as tree regeneration, hydrologic changes, soil erosion, and vegetation succession.

To facilitate application of existing predictive relationships, the equations, algorithms, and rules for calculating first order fire effects across the United States have been collected, organized, and integrated into a system designed to be used by land managers. The resulting system is the First Order Fire Effects Model or FOFEM. It is an easy to use, accessible computer program that predicts fuel consumption, smoke production, and tree mortality for many forest types in the United States.

## DESCRIPTION AND FEATURES OF THE MODEL

### Fire Effects Predicted by FOFEM

FOFEM currently has predictive capability for fuel consumption, tree mortality, and smoke production. Fuel consumption predictions are provided for litter, duff, herbs, shrubs, regeneration, 0- to 1-inch (1 and 10 hour) woody fuels, 1- to 3-inch (100 hour) woody fuels, and 3 + inch (1,000 hour) woody fuels. Predictions are provided both as loadings (tons/acre), and percent of preburn loading. Duff depth reduction and mineral soil exposure are also predicted. Tree mortality is described both as probability of mortality for an individual tree, and stand mortality in terms of percent mortality and postburn stand tables. Smoke production is predicted as pounds/acre of total particulate and PM10, or particulate less than 10 microns. Future versions of FOFEM are expected to provide predictions of soil heating, and additional smoke outputs, such as combustion efficiency of a fire.

### National in Scope

The United States is divided into four zones to account for the regionality of many of the empirical equations collected from the literature: Pacific West, Interior West, Northeast, and Southeast. All predictive equations and algorithms in FOFEM are stratified by these zones.

### Prediction and Planning Modules

In addition to predicting fire effects, FOFEM has a planning module. This allows a user to specify desired fire effects and have FOFEM compute the conditions necessary to achieve these objectives. This module is very useful for developing fire prescriptions.

### Minimal Input Required

FOFEM provides realistic default values for most inputs. The user can easily replace defaults with actual or estimated values. Many defaults are provided through a series of fuel loading models. Fuel loading models are available for most forest cover types in the United States, for both natural and slash fuels. These models provide preburn loadings for duff, litter, herbs, shrubs, regeneration, and woody fuels by size class in typical, light, and heavy fuel situations.

## IMPLEMENTATION AND AVAILABILITY

FOFEM is currently available as an operational prototype for evaluation and review. FOFEM is implemented for PC (IBM compatible, with math coprocessor) or Data General. An extensive user network is available for Forest Service users. To obtain a copy of FOFEM, contact the authors (406 329-4800); Forest Service employees can send a Data General E-mail message to: B.Keane:S22L01A.

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# Fire Effects Monitoring in Sequoia and Kings Canyon National Parks

**MaryBeth Keifer**
**Peter M. Stanzler**

The fire management goals for Sequoia and Kings Canyon National Parks include: protecting public safety, cultural and natural resources, and developments from wildfire, and restoring or maintaining the natural fire regime to the maximum extent possible. Reducing fuels that are hazardous to developments and to cultural and natural resources is a specific objective of the fire management program. The National Park Service (NPS) Wildland Fire Management Guideline (NPS 1990) mandates that all prescribed fires within the parks will be monitored and evaluated. The Western Region Fire Monitoring Handbook (NPS 1992) establishes a four-level protocol for monitoring fires and their biological effects for all parks in the Western Region. By monitoring, we are attempting to:

- Determine if fire management objectives are being met
- Assess ways to refine the prescribed fire program to achieve the objectives if they are not being met and
- Document visual, physical, and ecological effects of fire.

## METHODS

Permanently marked 20-m (66 ft) x 50-m (164 ft) forest plots were established in the giant sequoia/mixed conifer forest monitoring type at various locations in Sequoia and Kings Canyon National Parks. This monitoring type occurs between 1,675 m (5,500 ft) and 2,195 m (7,200 ft) elevation. Tree species present include a mixture of giant sequoia (*Sequoiadendron giganteum*), white fir (*Abies concolor*), red fir (*Abies magnifica*), sugar pine (*Pinus lambertiana*), ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*), and incense-cedar (*Calocedrus decurrens*).

Variables monitored include fuel load (Brown and others 1982), brush, seedling and tree density, and herbaceous cover. Burned plots are monitored pre-burn, immediately post-burn, 1, 2, 5, and 10 years post-burn, and every subsequent 10 years post-burn. Unburned plots are monitored initially, then 1, 2, 5, and 10 years afterward, and every subsequent 10 years. Burn prescription ranges for this monitioring type include: 30 to 90 °F air temperature, 20 to 60% relative humidity, 0 to 4 mph mid-flame windspeed, 10 to 20% 1,000-hour time lag fuel moisture, 0.5 to 2.5 ft flame length, 1 to 3 chains per hour backing rate of spread. Results are presented here for two of the variables in both burned and unburned plots in the giant sequoia/mixed conifer forest monitoring type: (1) fuel load in tons per acre (woody and litter/duff components), and (2) live tree count for giant sequoia and white fir trees by 10-cm diameter class. For more detailed methods, refer to the Fire Monitoring Handbook (NPS 1992).

## RESULTS AND DISCUSSION

### Fuel Load

In burned plots, the mean fuel load decreased from the pre-fire inventory to the 1-year post-fire inventory (Figure 1a). A larger proportion of litter and duff was reduced compared with woody fuels following prescribed burning in

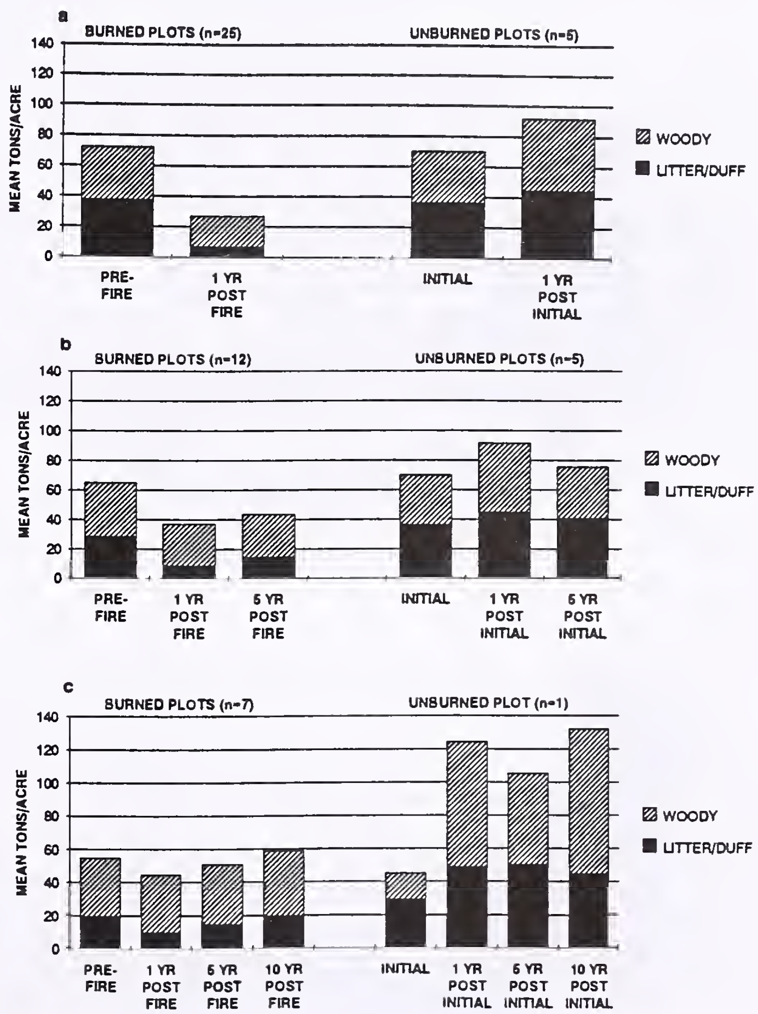


**Figure 1**—Mean total fuel load (tons/acre) for burned and unburned plots over (a) 1-year period, (b) 5-year period, and (c) 10-year period. Total fuel load is separated into woody and litter/duff components.

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this forest type. Total fuel load generally increased from the 1-year post-fire to the 5-year post-fire inventory and exceeded pre-fire levels after 10 years (Figures 1b and 1c). This result suggests that some areas in the giant sequoia/ mixed conifer forest may be burned for purposes of fuel reduction at intervals as short as 10 years.

In unburned plots, fuel load generally increased over time (Figure 1). Ten years after the initial inventory, fuel load in one unburned plot more than doubled, primarily due to an increase in woody fuels (Figure 1c). A large tree fell in this plot sometime prior to the 1-year post-initial inventory; therefore, this increase is probably not typical of unburned areas. Fluctuations in unburned plot fuel load over time may also be attributable to log movement and decomposition occurring along fuel transects in the small sample of unburned plots. Note that the number of plots included in the means varies by burned and unburned plots, as well as by duration of monitoring.

## Live Tree Inventory

The amount of mortality in burned plots varied by species and size class. The number of live white fir in the smallest diameter classes (2.5-10 cm and 10.1-20 cm) was greatly reduced 1 year following prescribed burning (Figure 2a), while little mortality occurred in the unburned plots (Figure 2b). Five- and 10-year inventories reveal that the

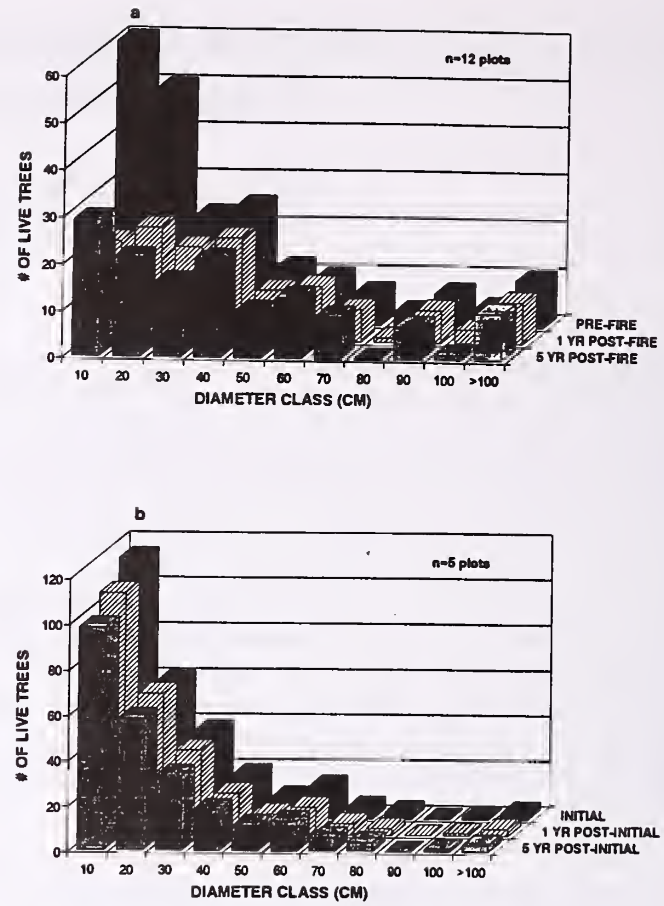


Figure 3—White fir live tree inventory by 10-cm size class over a 5-year period in (a) burned plots and (b) unburned plots.

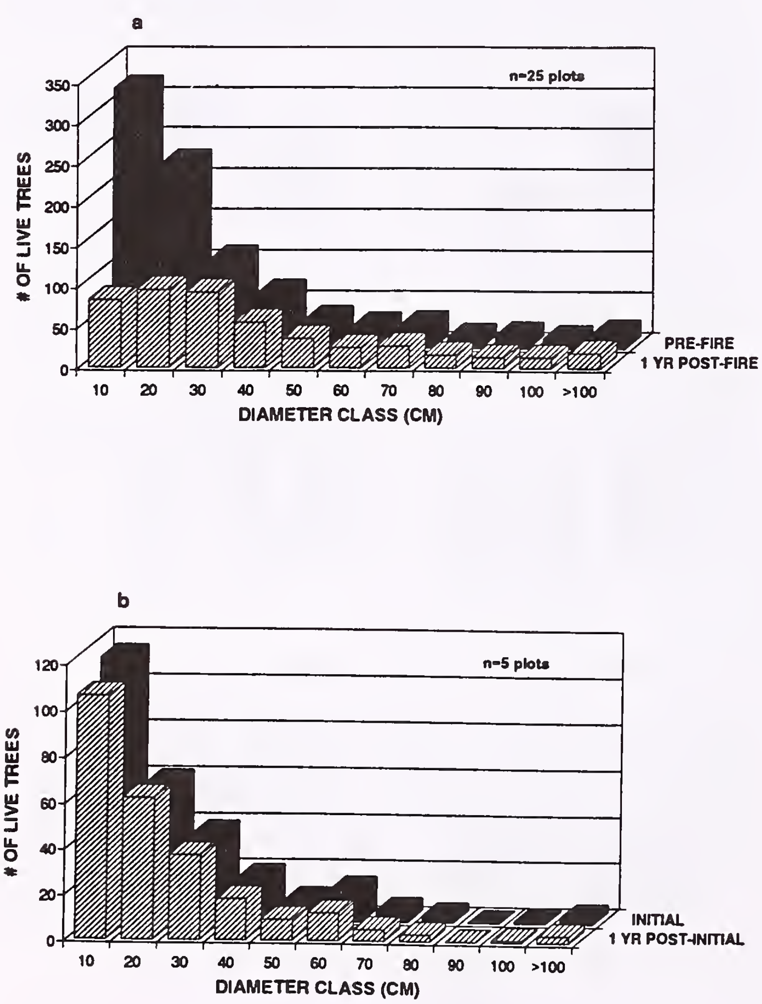


Figure 2—White fir live tree inventory by 10-cm size class over a 1-year period in (a) burned plots and (b) unburned plots.

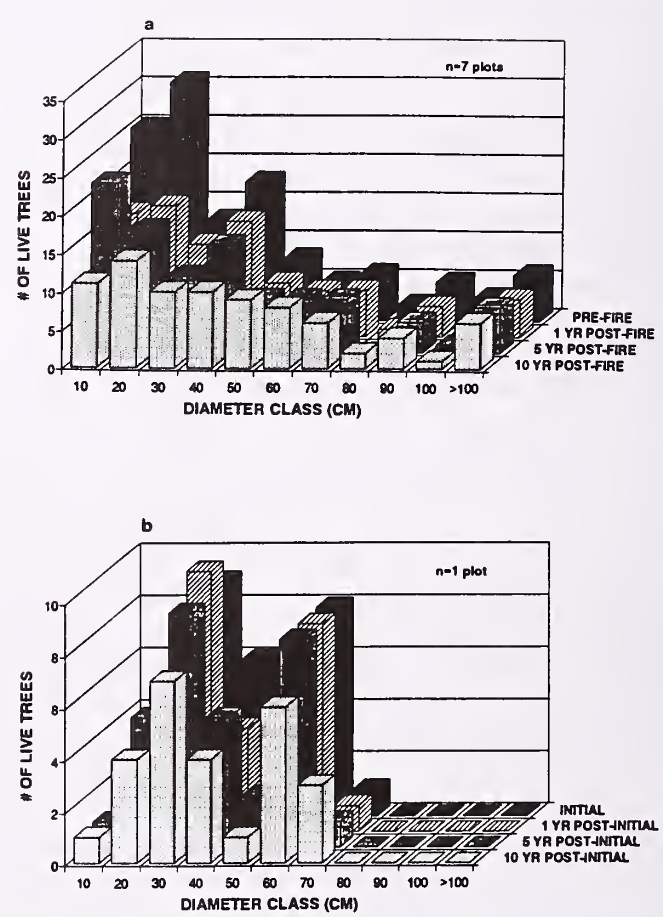


Figure 4—White fir live tree inventory by 10-cm size class over a 10-year period in (a) burned plots and (b) unburned plots.

number of live trees in the smaller diameter classes remained stable or fluctuated slightly for white fir in both the burned (Figures 3a and 4a) and unburned plots (Figures 3b and 4b). The number of white fir in the larger diameter classes generally remained stable from pre-fire or pre-initial through 10-year post-burn or post-initial inventory in both burned and unburned plots (Figures 2-4). These results indicate that prescribed burning in this forest type decreases the number of trees in the smaller size classes.

For giant sequoia, the number of live trees in the smaller size classes also decreased in burned plots (Figure 5a), although not as drastically as for white fir (Figure 2a). No smaller giant sequoia trees were present for comparison in unburned plots (Figure 5b). A marked increase in recruitment of giant sequoias in the 2.5- to 10-cm diameter class is evident 5 and 10 years post-fire in the burned plots (Figures 6a and 7a), while no giant sequoia recruitment occurred in the unburned plots during this time period (Figures 6b and 7b). Although sample size in unburned plots is low, these results suggest that prescribed burning may increase giant sequoia recruitment. The number of giant sequoia in the larger diameter classes remained stable from pre-fire to 10-year post-burn inventory (Figures 5-7). The lack of mortality of large giant sequoias in burned plots in this study indicates that this type of prescribed burning does not seriously threaten the large giant sequoia trees. Increased sample size will help to verify these results.

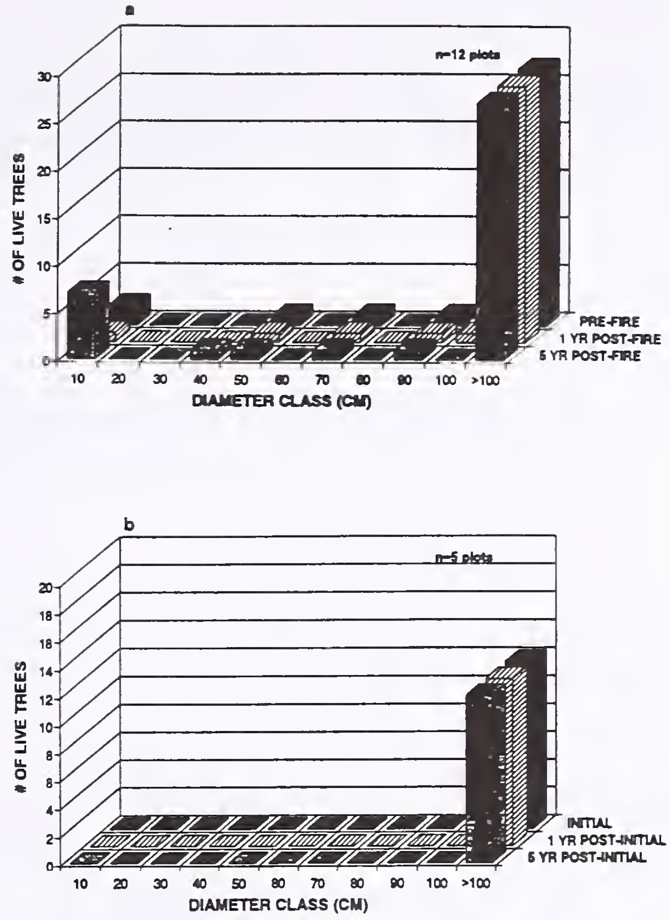


**Figure 6**—Giant sequoia live tree inventory by 10-cm size class over a 5-year period in (a) burned plots and (b) unburned plots.

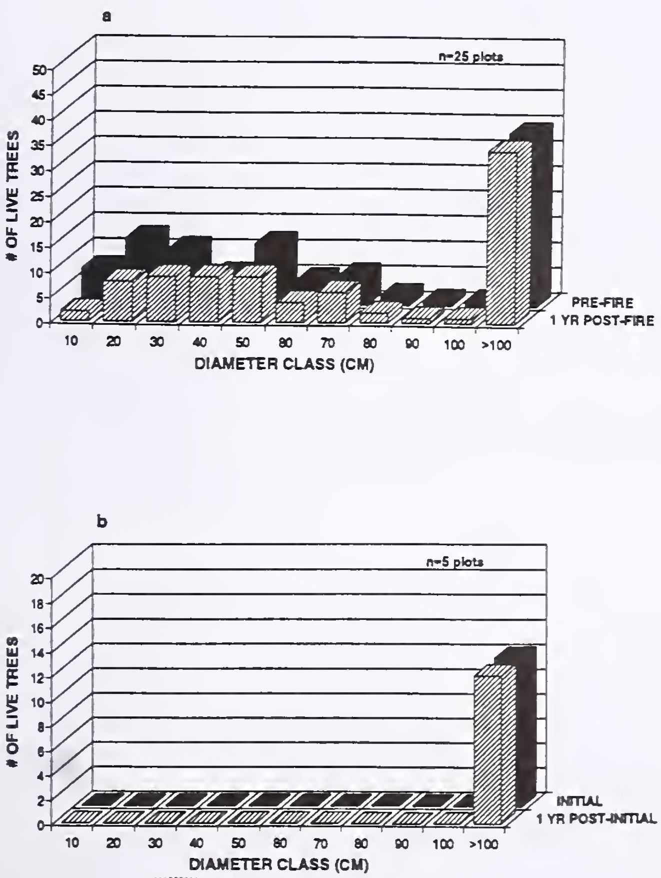


**Figure 5**—Giant sequoia live tree inventory by 10-cm size class over a 1-year period in (a) burned plots and (b) unburned plots.

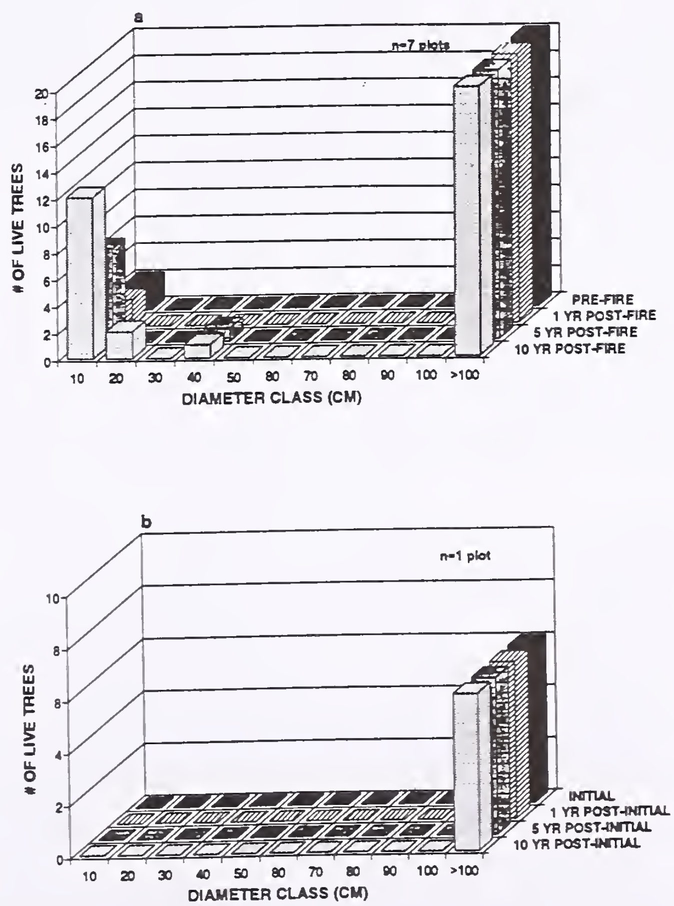


**Figure 7**—Giant sequoia live tree inventory by 10-cm size class over a 10-year period in (a) burned plots and (b) unburned plots.

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# Prescribed Fire in Two Prairies in the North Fork of the Flathead River Valley of Glacier National Park

**Laurie L. Kurth**
**Nathan C. Benson**

The 1988 fire season forced serious thought regarding fire management policies, culminating with a national review of these policies. As a result, all National Parks updated their fire management plans. Glacier National Park's new plan expanded the use of prescribed fire, as a management tool, to the entire Park.

Fire is a significant ecological force responsible for the diversity and mosaic distribution of vegetation communities. In Glacier National Park, fire plays an important role in a variety of communities including alpine meadows, subalpine forests, old-growth Douglas-fir forests, cedar-hemlock forests, ponderosa pine savannas, and open prairies. Much of the Park's vegetation diversity can be attributed to fire.

Fire frequencies vary throughout the Park. Fire histories west of the Continental Divide indicate mean fire intervals of 17 to 68 years in the forests of the North Fork of the Flathead River valley; forests to the south have intervals from 130 to 450 years (Barrett 1983, 1986, 1988). Barrett (1983) estimated that fires burned through the North Fork valley grasslands at least once every 20 years.

Changing land management objectives outside the Park and fire suppression have contributed to a decrease in fire frequencies. In the North Fork valley, many plant communities, especially prairies, have greatly exceeded their fire intervals. Therefore, many of these communities may be in an "unnatural" state.

Restoring fire to its natural role is one of the key objectives of Glacier National Park's fire management program (Glacier National Park 1991). In keeping with this objective, two management-ignited prescribed fires were conducted in the fall of 1992 in two of the North Fork grasslands, Big Prairie and Round Prairie.

This poster addresses: 1) the goals of the burns, 2) monitoring used to determine if the goals were met, and 3) initial data analysis and results.

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## BURN SITE DESCRIPTIONS

### Big Prairie

This burn unit includes 22 acres along the North Fork of the Flathead River (figure 1). Fifty-five percent of the burn area is short-grass prairie. The dominant grasses are rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), and Richardson's needlegrass (*Stipa richardsonii*). A variety of forbs are also found. Thirty-five percent of the burn area is open ponderosa pine (*Pinus ponderosa*) savannas with an understory of grasses and forbs. The remaining 10 percent of the site is characterized by dog-hair lodgepole pine (*Pinus contorta*) inclusions.

### Round Prairie

This burn unit includes 60 acres along the North Fork of the Flathead River (figures 2 and 3). Thirty-five percent of the unit is short-grass prairie similar to that of the Big Prairie site. Another 35 percent is sagebrush grassland dominated by big sagebrush (*Artemisia tridentata*). Grasses and forbs, although present, are sparse. The remaining 30 percent of the burn unit includes a mixture of Engelmann spruce (*Picea engelmannii*), Douglas-fir (*Pseudotsuga menziesii*), and lodgepole pine forests.

## GOALS OF THE BURNS

Lack of fire in the prairies was evident by the numerous young lodgepole pine trees at the forest-prairie interface and scattered throughout the prairie. Additionally, numerous down trees contributed to moderately high fuel loads within the forest inclusions. The following goals were designed to mitigate these conditions:

- Reduce tree encroachment into prairies by decreasing the number of trees less than 2.5 cm dbh by 70 to 100 percent and trees 2.5 cm to 7.5 cm dbh by 30 to 70 percent
- Reduce fuel loadings in the forest inclusions by 30 to 70 percent
- Sustain less than 10 percent mortality of ponderosa pine trees larger than 5 cm dbh in Big Prairie
- Reduce sagebrush cover by 50 to 90 percent in Round Prairie
- Encourage proliferation of native grassland species by increasing canopy cover of native species by 10 to 30 percent the first growing season following the fire.

**Figure 1**—Big Prairie before the burn.

**Figure 3**—Round Prairie tree encroachment transect before the burn.

Also, the fires served as training, helping park employees meet certification requirements. Data collected during the fires augmented the Park's ecological database.

## MONITORING

In order to determine if the goals were achieved, ecological and fire behavior monitoring programs were initiated. Monitoring methods were developed by modifying the Park's draft fire monitoring plan (Glacier National Park 1988) and the Forest Service's ECODATA handbook (1987).

### Ecological Monitoring

Three 20-meter by 50-meter macroplots were randomly established in each community type at each burn site. Vegetation cover was estimated and tree diameters and fuel loads (Brown 1974) were measured in the plots.

Tree encroachment transects were randomly located along the forest-prairie edge. Species, status (alive, dead, fallen), dbh, height, and location were recorded for each tree in the transect. Following the burn, percent crown scorch was estimated. Probability of mortality based on crown scorch and tree size was calculated using a model developed by Ryan and Reinhardt (1988).

**Figure 2**—Round Prairie before the burn.

### Fire Behavior Monitoring

Fuel moisture was measured daily beginning several days before ignition. Immediately prior to the burns, temperature sensors made with temperature-sensitive paint (Cole and others 1992) were placed in the macroplots, tree transects, and at random locations within the burns. Fire weather was taken at 30-minute intervals starting 1 hour before the burns and continuing throughout the burning period. While the fire was burning, flame lengths, rate of spread, and smoke production were estimated every 15 minutes.

## RESULTS

The Big Prairie burn was conducted on September 22 and the Round Prairie burn was conducted on October 1. Burning conditions were less favorable in Round Prairie; thus, the fire behavior was less intense (tables 1 and 2). High fuel moisture in the forest inclusions and lack of wind led to little burning in the forests and virtually no fire in the sagebrush area of Round Prairie.

**Table 1**—Summary of fire weather. The abbreviation R. H. stands for relative humidity

| | Big Prairie | Round Prairie |
|---|---|---|
| Burn date | September 22, 1992 | October 1, 1992 |
| Fuel moisture (percent) | | |
| 1-hr | 13 | 11 |
| Live | 34 | 50 |
| Ignition time weather | | |
| Temp. (degrees F) | 68 | [1]68 |
| R. H. (percent) | 56 | |
| Wind speed (mph) | 1.5 to 7 | |
| Wind direction | SSE | |

[1]Temperature from West Glacier, on-site weather information not available.

**Table 2**—Summary of fire behavior

| Fire behavior | Big Prairie Average | Big Prairie Range | Round Prairie Average | Round Prairie Range |
|---|---|---|---|---|
| Flame length (feet) | 2.2 | .5 to 10 | 2.1 | .3 to 4 |
| Rate of spread (ft/min) | 15 | 1.8 to 60 | 9.4 | 1.2 to 30 |
| Smoke volume | | light to moderate | | light to moderate |
| Temp. (degrees F) | | | | |
| Inches above ground | | | | |
| 0 | 452 | 0 to >1,220 | 80 | 0 to 400 |
| 6 | 407 | 0 to >1,220 | 105 | 0 to 1,200 |
| 12 | 335 | 0 to >1,220 | 85 | 0 to 900 |
| 18 | 279 | 0 to >1,220 | 75 | 0 to 800 |
| 30 | 158 | 0 to >1,220 | 20 | 0 to 500 |
| 42 | 149 | 0 to >1,220 | 33 | 0 to 400 |

Initial analysis of the tree encroachment transects shows that the burns were successful in killing some of the encroaching trees (figures 4 through 9, tables 3, 4 and 5). In Big Prairie 9 percent of lodgepole pine trees were observed dead following the fire and 100 percent are predicted to be dead. Lower rates of mortality (3 percent observed and 80 percent predicted) in Round Prairie are expected due to the burning conditions. The model used may over predict mortality for lodgepole pine that burns in a very low intensity fire (Kevin Ryan, USFS, personal communication). Trees will be followed through several years to determine actual mortality and other agents (fungus, beetles) that contribute to mortality following fire.

Analysis of fuel loads, ponderosa pine mortality, and grassland species composition and cover will be completed following the 1993 field season.

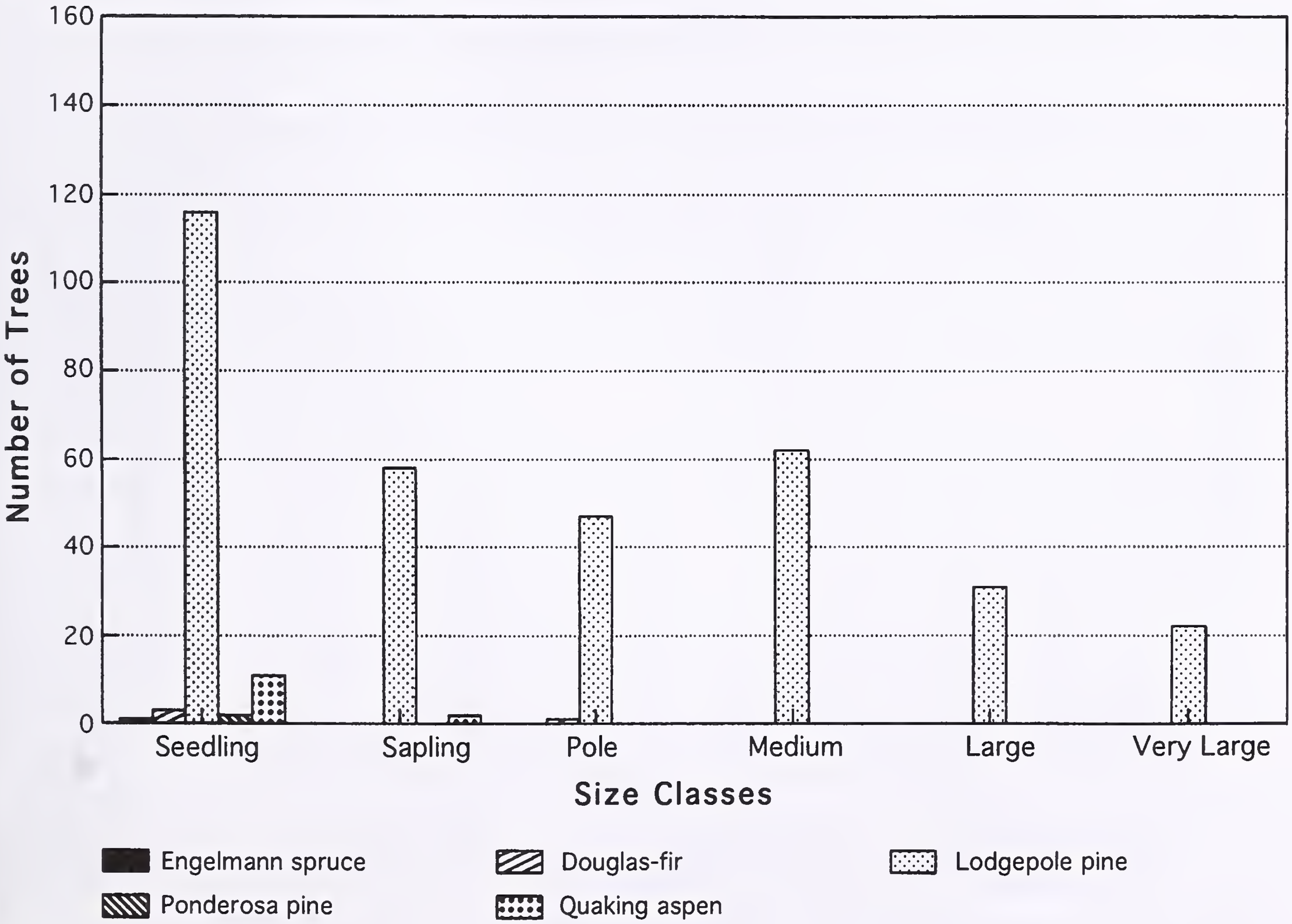


**Figure 4**—Big Prairie preburn live tree composition by size class.

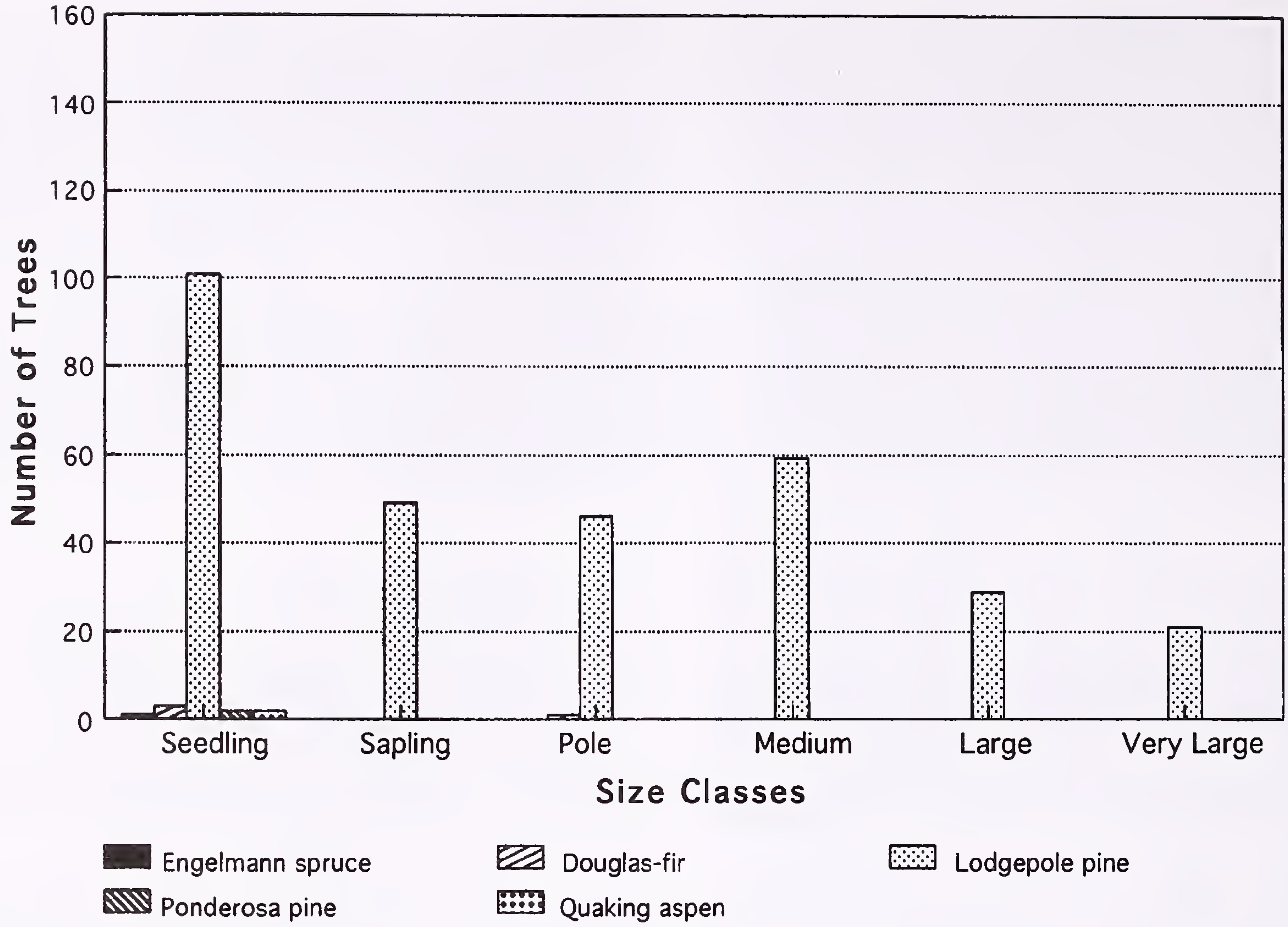


**Figure 5**—Big Prairie postburn observed live tree composition by size class.

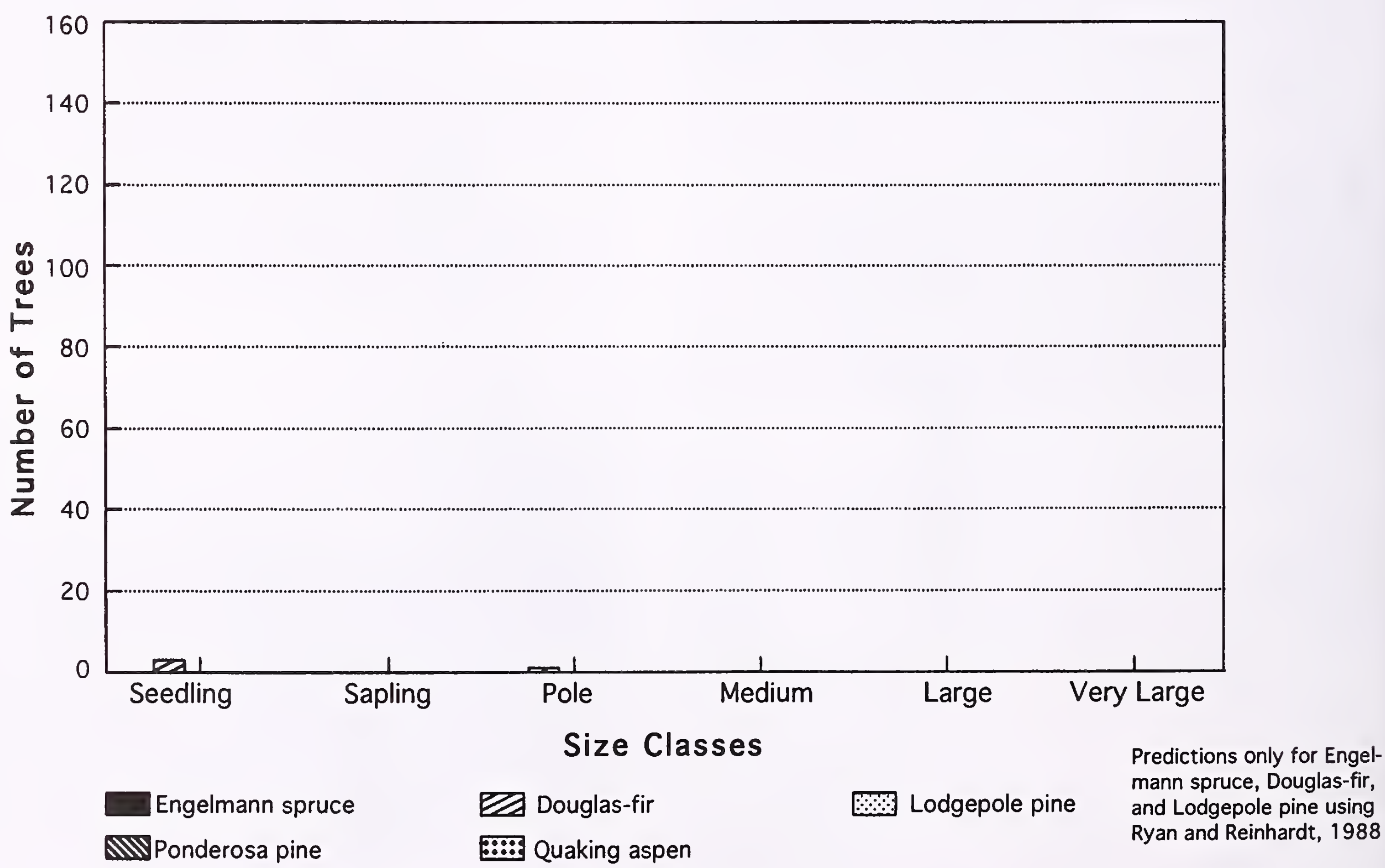


**Figure 6**—Big Prairie postburn predicted live tree composition by size class.

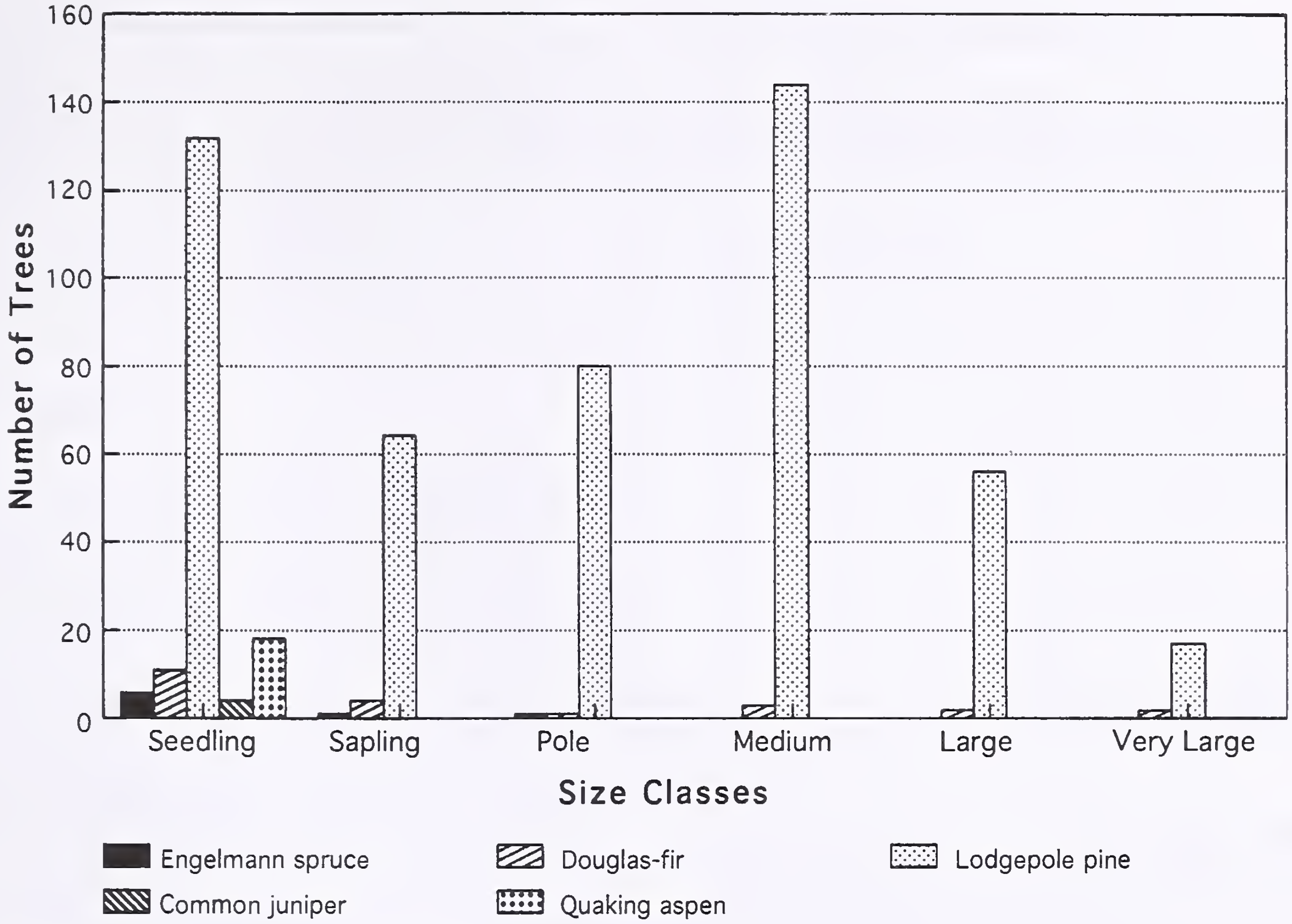


**Figure 7**—Round Prairie preburn live tree composition by size class.

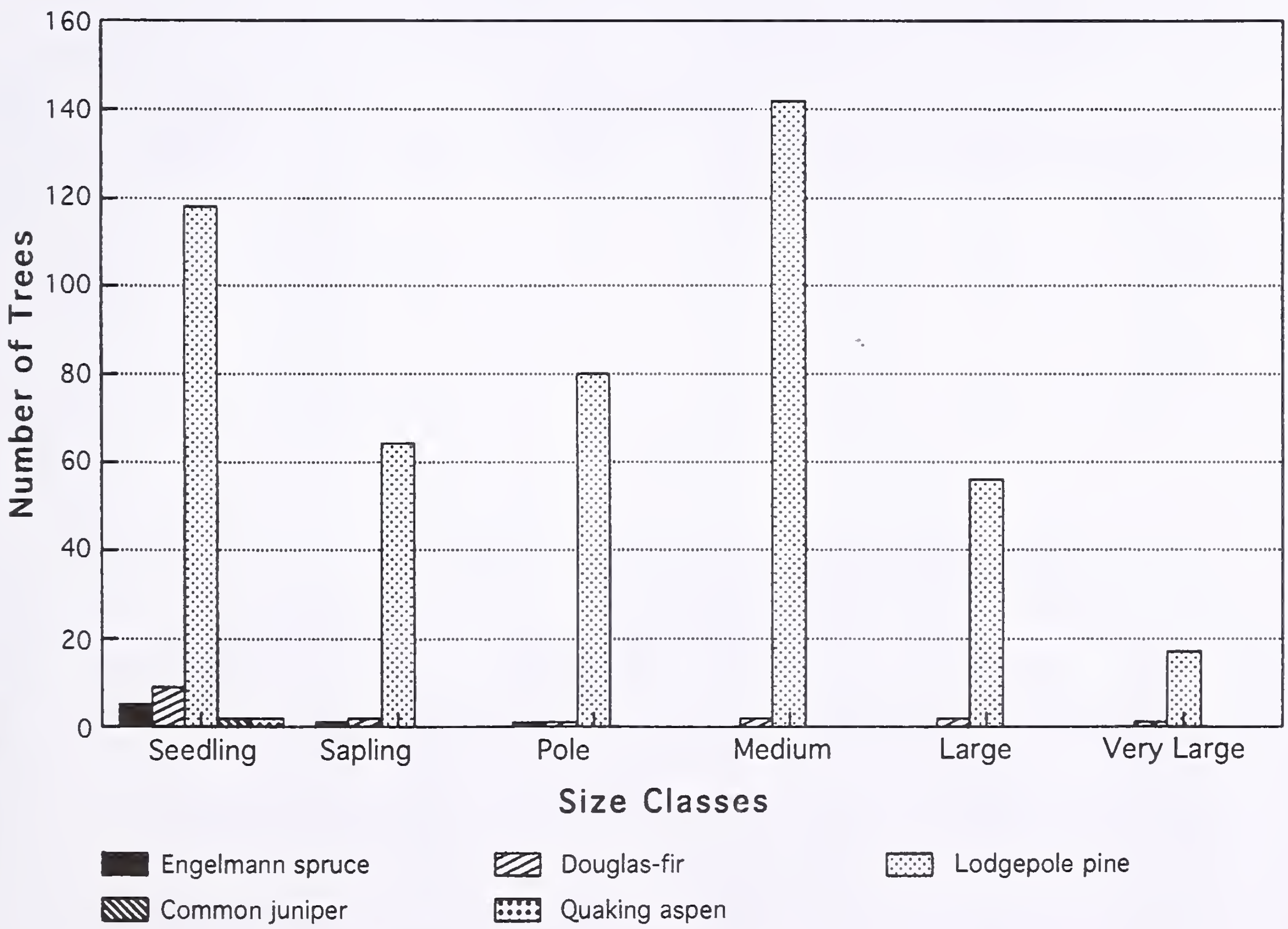


**Figure 8**—Round Prairie postburn observed live tree composition by size class.

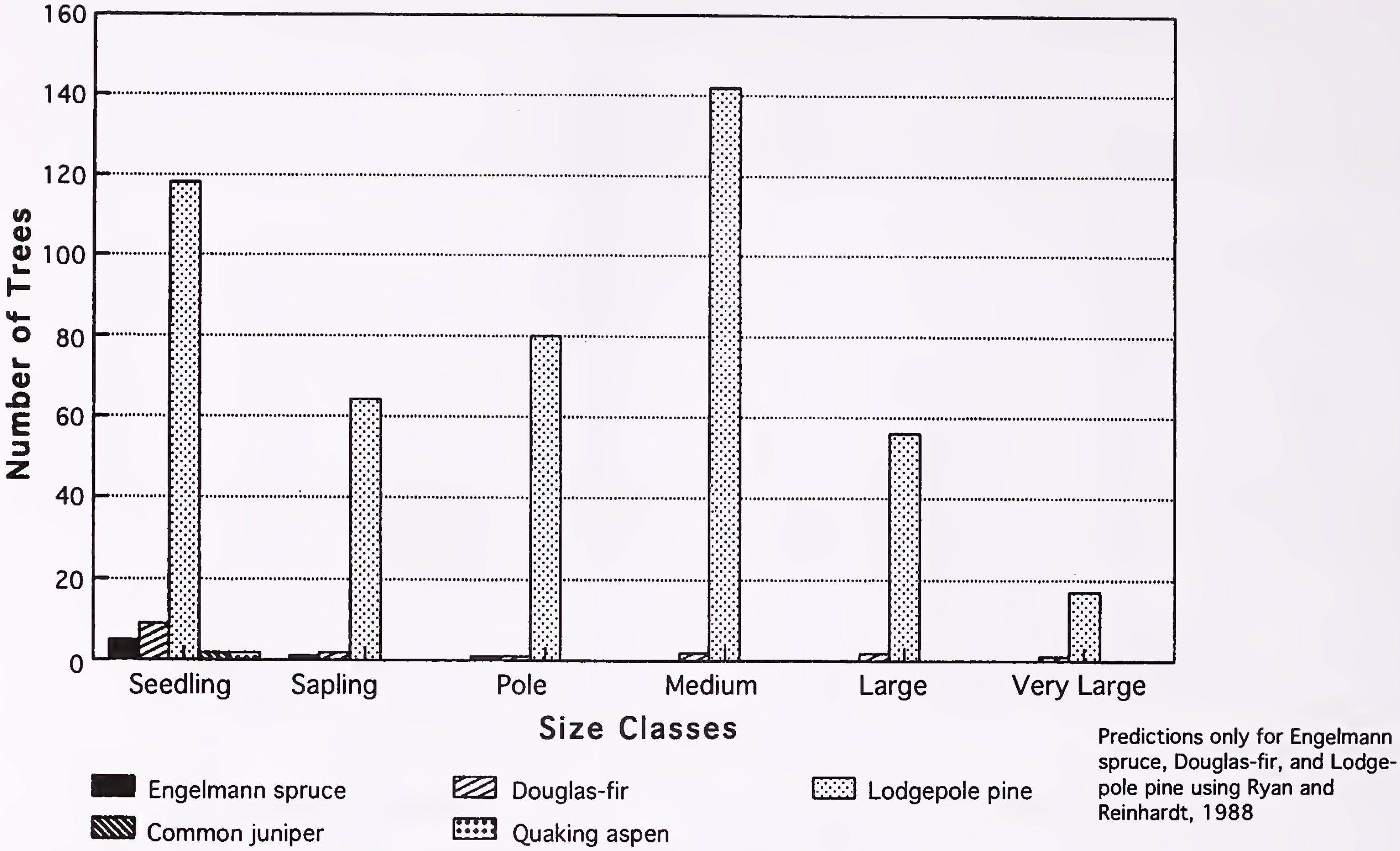


**Figure 9**—Round Prairie postburn predicted live tree composition by size class.

**Table 3**—Number of preburn alive lodgepole pine, postburn dead lodgepole pine, and predicted dead lodgepole pine on Big Prairie tree transects

| Size class | Preburn alive | Postburn observed dead: Dead | % | % combined classes | Predicted dead: Dead | % | % combined classes |
|---|---|---|---|---|---|---|---|
| Seedling | 116 | 15 | 13 | 14 | 116 | 100 | 100 |
| Sapling | 58 | 9 | 16 | | 58 | 100 | |
| Pole | 47 | 1 | 2 | 4 | 47 | 100 | 100 |
| Medium | 62 | 3 | 5 | | 62 | 100 | |
| Large | 31 | 2 | 6 | 6 | 31 | 100 | 100 |
| Extra large | 22 | 1 | 5 | | 22 | 100 | |
| Total | 336 | 31 | 9 | — | 336 | 100 | — |

**Table 4**—Number of preburn alive lodgepole pine, postburn dead lodgepole pine, and predicted dead lodgepole pine on Round Prairie tree transects

| Size class | Preburn alive | Postburn observed dead: Dead | % | % combined classes | Predicted dead: Dead | % | % combined classes |
|---|---|---|---|---|---|---|---|
| Seedling | 132 | 14 | 11 | 7 | 94 | 71 | 74 |
| Sapling | 64 | 0 | 0 | | 52 | 81 | |
| Pole | 80 | 0 | 0 | 1 | 68 | 85 | 85 |
| Medium | 144 | 2 | 1 | | 122 | 85 | |
| Large | 56 | 0 | 0 | 0 | 44 | 79 | 78 |
| Extra large | 17 | 0 | 0 | | 13 | 76 | |
| Total | 493 | 16 | 3 | — | 393 | 80 | — |

**Table 5**—Size classes of trees in figures 4-9

| Size class | DBH in centimeters |
|---|---|
| Seedling | no dbh (height < 1.6 meter) |
| Sapling | dbh < 2.5 (height > 1.6 meter) |
| Pole | 2.5 to 22.7 |
| Medium | 22.8 to 53.2 |
| Large | 53.3 to 83.7 |
| Extra large | dbh < 83.7 |

## DISCUSSION

Initial data analysis indicates that the burn goals have been partially met. If actual tree mortality approaches the prediction, then the goal to reduce tree encroachment will have been exceeded. High predicted mortality in Round Prairie indicates that burning in marginal conditions may be beneficial if the primary goal is to reduce lodgepole pine encroachment. However, the Round Prairie burn failed to reduce sagebrush cover. To achieve this goal the prairie must burn under hotter, drier, and windier conditions. A comparison of the native grass and forb covers between Big Prairie and Round Prairie and analysis of postburn fuel loads are necessary to further determine the success of the burns.

Vegetation dynamics in Glacier National Park are dependent on fire; however, an active prescribed fire program has been slow in starting. The two management-ignited prescribed fires in 1992 were the first conducted since 1983. They are significant in that some of the goals were accomplished and they represent progress towards an active prescribed fire program. Using the information and experience from these burns, plans for future burns are being formulated.

## ACKNOWLEDGMENTS

A special thanks to the Red Bench Crew (1990 to 1992), the Hazard Fuel Crew, the Fire Cache, and our GIS and Computer Specialists for their assistance on this project.

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# Quantifying Risk And Displaying Ecological Consequences of Prescribed Fire Decisions In The Boundary Waters Canoe Area Wilderness

**Richard J. Lasko**
**Paul R. Tiné**

Decisions regarding prescribed fire and wildfire challenge wilderness stewards to strike a balance between the immediate risk of a fire exiting a wilderness and the long-term ecological consequences of excluding fire from the ecosystem. Decisions based solely on risk avoidance will exclude fire from the ecosystem and modify vegetative composition. This course of action will severely limit future fire management options.

The application of a methodology to quantify the risk of a fire exiting the wilderness provides wilderness stewards with the ability to display and compare degrees of risk associated with wilderness fire management decisions. A methodology is also described which allows stewards to quickly assess the potential ecological consequences of go-no go decisions involving wilderness fire.

Prescribed fire decisions based on analysis which quantifies risk and assesses potential ecological consequences will contribute to sound stewardship of the wilderness resource.

## QUANTIFYING THE RISK OF FIRE EXITING THE BOUNDARY WATERS CANOE AREA WILDERNESS

The Rare Event Risk Assessment Process developed by Mark Wiitala and Donald Carlton is used to quantify the risk associated with undesirable fire movement resulting in the escape of a fire from the wilderness. This process is applied at both programmatic and site-specific levels of analysis.

### Programmatic Level

The programmatic level assessment establishes zones of risk potential to aid the fire manager in assessing the feasibility of prescribed natural fire operations or the application of management-ignited prescribed fire. This "strategic overview of risk" allows stewards to assess the capacity of their wilderness to sustain fire events within the wilderness boundary.

### Site-Specific Level

The site-specific level assessment quantifies risk associated with a fire at a specific point in space and time. This analysis is conducted when the fire is detected and provides the fire manager with a specific value of risk associated with the fire event.

## DISPLAYING THE ECOLOGICAL CONSEQUENCES OF PRESCRIBED FIRE DECISIONS IN THE BOUNDARY WATERS CANOE AREA WILDERNESS

Potential ecological consequences associated with prescribed fire decisions are graphically displayed in a decision tree format. Decision trees displaying potential ecological pathways are being developed for each vegetative community type in the Boundary Waters Canoe Area Wilderness.

Wilderness stewards use the decision trees to identify and document the ecological consequences that result from go/no go fire decisions.

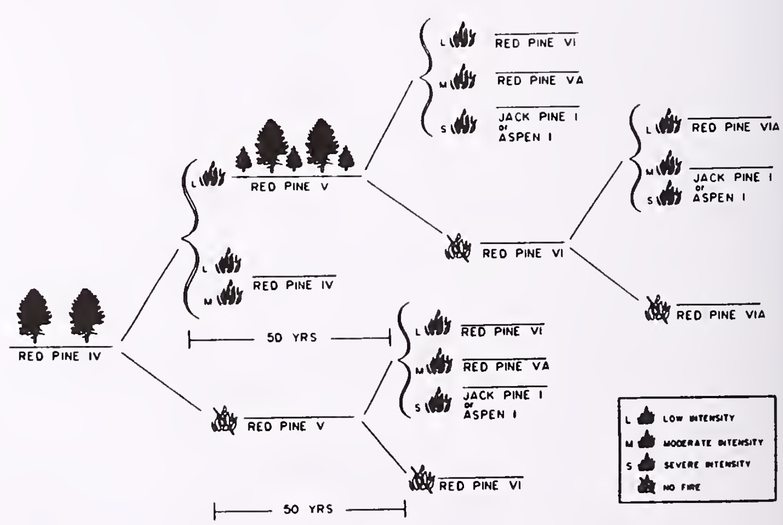


**Figure 1**—Potential ecological consequences associated with prescribed fire decisions are displayed graphically on decision trees. Decision trees displaying potential ecological pathways are being developed for each of 38 vegetation types in the Boundary Waters Canoe Area Wilderness. Beginning in 1993, wilderness stewards will be required to identify and document ecological consequences as well as risks associated with prescribed fire decisions.

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# Fuel Model Identification and Mapping For Fire Behavior Prediction in the Absaroka-Beartooth Wilderness, Montana and Wyoming

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Charles L. Bushey
Wayne Smetanka

The Absaroka-Beartooth Wilderness Prescribed Natural Fire Program was suspended after the severe 1988 fire season. All prescribed natural fire programs were suspended until they were reviewed for compliance with current national policy and direction. In addition, they had to meet the recommendations of the Interagency Fire Management Policy Review Team (Philpot and Leonard 1988). The Absaroka-Beartooth Wilderness Prescribed Natural Fire Program Review began in May 1991. The review will be completed by June 1993, producing guidelines and procedures for operating the prescribed natural fire program and guiding overall wilderness fire management.

The Fire Management Policy Review Team recommended that, "Current fire management plans in national parks and wilderness areas must be strengthened by developing joint agency fire management plans, agreements, or addendums to existing plans for those areas where fires could cross administrative boundaries." The Review Team also recommended "limits on projected length of active perimeter and acreage burned." The Task force on Prescribed Fire Management Criteria (Eubanks 1988) recommended that the analysis and decision process provide for risk assessment that considers existing and predicted weather, fuel conditions, and fire growth. The Absaroka-Beartooth Wilderness Fire Management Review Team had to develop resources and determine procedures to meet this direction. Estimating fire behavior potential hinges on how fuel moistures and fuel types vary throughout a fire area and during the fire's duration. An inordinate amount of time cannot be spent deciding what to do, while waiting for better information on weather and fuels. The Absaroka-Beartooth Team acknowledged that fuels information would be the key to strengthening the Absaroka-Beartooth Wilderness Fire Management Program and it would be absolutely necessary to improve fire growth and spread predictions.

In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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## AVAILABLE INFORMATION

The Absaroka-Beartooth Review Team quickly concluded that there was not adequate time nor funding to conduct any extensive field sampling. So, the first task was to ascertain what information was already available to us. Information was gleaned from three national forests and one national park. The following data was available to the Absaroka-Beartooth Review Team:

- TMSTAND (Timber Stand Data Base, USDA, 1988) photo interpretation data
- Shoshone National Forest vegetation cover-types generated from their GIS (Geographic Information System) data base
- Yellowstone National Park vegetation cover-types.
- Grizzly bear habitat type mapping
- Aerial photography for the Storm Creek and Hellroaring fires (1988).

Next, the Absaroka-Beartooth Review Team had to determine if this information could provide the fuels information they sought. The fire severity mapping and aerial photography offered recent, site-specific information that could readily be interpreted and assigned one of the 13 Fire Behavior Fuel Models (Anderson 1982). The timber stand data and the habitat typing presented another problem. This vegetation information was already mapped on 7.5-minute orthophoto quadrangles. But how do you derive fuel models from vegetation cover-types?

## PROBLEM ASSESSMENT

The TMSTAND data from the Custer National Forest consisted of non-forested and forested cover-types. The forested vegetation was further broken down by species, size class (age), crown density (canopy coverage), crown texture, and stand stocking level. The Gallatin National Forest TMSTAND data was also divided between non-forested and forested information, but crown density and texture data were not available. Also, non-commercial forests were not photo-interpreted. The grizzly bear habitat typing was similar to the Gallatin National Forest information, except the habitat typing had been ground-truthed. The Yellowstone National Park vegetation cover-types were developed from ground sampling, and subsequently updated from remote sensing (Landsat) data after 1988. The Yellowstone data overlapped the

Park's northern boundary into the Absaroka-Beartooth Wilderness for only a short distance, about 2 kilometers. The Absaroka-Beartooth Review Team had vegetation information that identified species, varying degrees of community structure, and some ground-truthed data. How do you make the jump to fuel model classification from this existing data?

An intermediate step had to be found, and it was uncovered in the Yellowstone National Park Wildland Fire Management Plan (USDI 1992). The Park had already described cover-types and equated those to fire behavior fuel models. So, the Absaroka-Beartooth Review Team decided to utilize the Park information and tailor it to fit our particular circumstances. This task was not as easy as it sounds. The Absaroka-Beartooth Review Team's contracted Prescribed Fire Planner had to develop a dichotomous key to meld the TMSTAND cover-types into Yellowstone's cover-types. Also, some additional cross-checking had to occur between the Gallatin's codes and the grizzly bear habitat typing to fill in some gaps where crown closure and texture information was lacking. For example, another vegetation cover-type classification was developed to represent forested areas with less than full stocking (40-69%), which would generally coincide with a fuel model 2 description. This additional cover-type was necessary to describe more open forest, where crown closure was not sufficient to propagate a crown fire.

## FUEL MODELING PROCESS

Lodgepole pine (*Pinus contorta* Dougl. var. *latifolia*) is the dominant cover-type. The size class is sawtimber (10% growing stock >5 inches [12.5 cm] D.B.H. [1.37 meters above forest floor], 5-8.9 inch [22.6 cm] class ≤9 inch [22.9 cm] or greater class). The stocking percent is utilized to establish a division between the LP4 and LP3 cover-types (Yellowstone National Park codes). LP4 represents a scattered forest structure that is less than 40% stocked by stand delineation. LP4 would likely reflect a fuel model 2, because fine herbaceous fuels would be necessary to promote fire spread under the open timber overstory. Open shrublands and pine stands may cover one-third to two-thirds of the area. LP3 represents the mature to overmature forest, but with greater stand stocking, which equates to a fuel model 10. LP3 is characterized by shade-tolerant trees emerging from the understory, and greater fuel loadings in the 3-inch (7.62 cm) and greater size class with a more continuous fuelbed than in fuel model 8.

The next division occurs with stands at greater than 40% stocking, where crown densities create a split amongst LP2, LP3, and LP4. Even though a stand may be 40 to 69% stocked, crown densities less than 60% would throw that stand into an LP4. Stands with greater crown densities, although composed of forest patches or islands, might best represent an LP2 or LP3 due to the higher stem densities and greater crown closure.

Texture codes, representing crown size, spacing, and stem density to some degree, determine breakdowns between LP2, LP3, and LP. The fine and medium-fine descriptors represent closed canopies, high stand stocking levels, minimal understory, and lower fuel loadings (>3 inches), which equates to a fuel model 8. Medium-coarse crown textures characterize more open stand conditions due to weather, insects, or disease, which equates to LP3 or fuel model 10. Coarse crown textures may indicate an

**Table 1**—An example illustrating the fuel model methodology. The abbreviation, "MHRS" stands for "mature high risk sawtimber"

| | Lodgepole pine fuel modeling | | | | | |
|---|---|---|---|---|---|---|
| Size class | Stocking percent | Crown density | Crown texture | Vegetation cover-type | Fire behavior fuel model | Remarks |
| Sawtimber | <10% | - - - - - -> | - - - - - -> | LP4 | 2 | |
| Sawtimber | 10-39% | - - - - - -> | - - - - - -> | LP4 | 2 | |
| Sawtimber | 40-69% | 40-60% | - - - - - -> | LP4 | 2 | |
| Sawtimber | 40-69% | 61%+ | Fine or medium fine | LP2 | 8 | MHRS - - ->LP3 |
| Sawtimber | 40-69% | 61%+ | Medium coarse | LP3 | 10 | >30% Rock - - - - - - >LP4 |
| Sawtimber | 40-69% | 61%+ | Coarse | LP | 10 | >30% Rock - - - - - - - - - ->LP4 |
| Sawtimber | 70%+ | 40-60% | - - - - - -> | LP4 | 2 | |
| Sawtimber | 70%+ | 61%+ | Fine or medium fine | LP2 | 8 | MHRS - - ->LP3 |
| Sawtimber | 70%+ | 61%+ | Medium coarse | LP3 | 10 | >30% Rock - - - - - - - ->LP4 |
| Sawtimber | 70%+ | 61%+ | Coarse | LP | 10 | >30% Rock - - - - - ->LP4 |

overmature lodgepole pine overstory allowing enough light to reach the forest floor to support a vigorous understory of ladder fuels. Loadings of greater than 3-inch diameter fuels are increased, causing higher fire intensities leading to crowning, torching, and spotting without wind. The LP cover-type describes this overmature forest successional stage, which corresponds to a fuel model 10.

Two further conditions are noted in the remarks, MHRS (mature high risk sawtimber) and "more than 30% rock". Sawtimber is defined as mature high risk sawtimber when at least 40% of the stand, as measured by basal area, is affected by damaging disease or insects. These conditions would throw a LP2 into a LP3. Rock outcrop and scree have a definite effect on stand classification. The greater proportion of rock would move a LP3 or LP stand into an LP4. Fine, herbaceous fuels would be necessary to facilitate fire spread, but isolated fuel jackpots could torch and promote spotting among timber islands.

## DISCUSSION

The previously described methodology was implemented throughout the Absaroka-Beartooth Wilderness. Gallatin National Forest stands, identified as non-commercial or lacking crown density and texture data, had to be cross-checked with the grizzly bear habitat type information before assigning a cover-type and associated fuel model.

The vegetation cover-types were mapped on 1:24,000 topographic map quadrangles. Orthophoto base maps (1:24,000) with photo-delineated stand boundaries were utilized as a starting point. Stands with similar vegetation cover-types (fuel models) were combined to create larger polygons. Fire perimeter and intensity mapping for the Storm Creek, Hellroaring, and Clover Mist fires provided key information in burned areas to complement cover-type interpretation and assign fuel models. The map overlays are indexed by quadrangle, edge-fitted, and referenced so that they can be digitized into a geographic information system at a later date.

This cover-type analysis and mapping supplies essential existing conditions to assess risk through fire growth predictions. Fuel model typing is critical to maximum allowable perimeter development and tactical holding strategies for prescribed natural fire management. Vegetation mapping integrated with topography and past fire patterns helped form fire management units with defensible boundaries. Greater Yellowstone Area coordination should improve when managers analyze fires with potential to cross administrative boundaries. Managers responsible for the Absaroka-Beartooth Wilderness and Yellowstone National Park can now speak the same language.

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# Fire Management Considerations for BLM Wilderness Areas

**Melanie Miller**
**Carl Gossard**
**Ken Mahoney**

Wilderness management is a relatively new program within the Bureau of Land Management (BLM) because BLM lands were not included in the original Wilderness Act of 1964. The passage of the Federal Land Policy and Management Act in 1976 gave the BLM authority to study its lands and make recommendations to the President about the suitability of lands for inclusion in the National Wilderness Preservation System. The BLM presently manages 66 designated Wilderness Areas in nine Western States, as well as 745 Wilderness Study Areas covering 26.6 million acres.

Arizona is the only state in which a state-wide system of BLM-managed Wilderness Areas has been designated by Congress. The BLM manages 1.4 million acres of Arizona Wilderness, located in 47 units. Legislation is pending for the other Western States that would designate additional BLM Wilderness Areas. Wilderness Study Areas are to be managed so as not to affect their eligibility to be included in the Wilderness Preservation System.

The BLM Wilderness Areas include many ecosystems that are poorly or not previously represented within the National Wilderness Preservation System. The natural role of fire may be quite different than in Wilderness Areas managed by other Federal agencies. Fire has been an uncommon occurrence in some habitats, or may now occur more frequently than in the past because of changes in plant species composition, or invasion by exotic species, caused by human management activities. Unique opportunities and challenges are faced by the BLM in making fire management decisions for these areas. Is prescribed natural fire, prescribed burning, or complete fire exclusion the appropriate fire management strategy? Some Arizona Wilderness Areas are described that illustrate some of the ecological issues and management considerations that the BLM must address.

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## MOHAVE DESERT

### Grand Wash Cliffs Wilderness Area, Arizona Strip District

The 37,030-acre Grand Wash Cliffs Wilderness is located 35 miles south of St. George, Utah. Filled with rugged canyons, scenic escarpments, miles of towering cliffs, and sandstone buttes, the Wilderness marks the transition zone between the Colorado Plateau and the Basin and Range provinces. The area's vegetation contains a mixture of Mohave desert shrubs, annual grasses and forbs, and pinyon-juniper (*Pinus* spp.-*Juniperus* spp.) woodland from colder desert country.

**Joshua Tree/Blackbrush**—Fire did not play a significant role in Joshua tree/blackbrush (*Yucca brevifolia* Engelm./*Coleogyne ramosissima* Torr.) communities in the Mohave Desert because native annual vegetation was rarely continuous enough to carry fire. The invasion of the exotic annual grass, red brome (*Bromus rubens* L.), has provided a more consistent source of fine fuels. In years with a precipitation regime favorable to red brome germination and establishment, fuel loadings are high enough to support large wildfires. These fires convert the native Mohave Desert vegetation to an annual grassland. Joshua trees are killed by repeated high-intensity fire, and blackbrush is eliminated by burning. If no action is taken, much of the Mohave Desert in northwest Arizona will lose its cover of native vegetation.

Management options include an increased level of fire protection to limit fire size, and vegetation restoration. Native vegetation could be established through planting, perhaps in islands that could serve as sources of seed for adjacent areas. Careful grazing management would be required to maintain the competitive advantage of native species over red brome.

**Creosote Bush**—Creosote bush (*Larrea tridentata* [DC.] Coville) is a dominant or codominant species in some desert shrub and southwestern shrub steppe ecosystems. It is considered to be an invader species in Southwestern desert grasslands. The expansion of creosote bush has been attributed both to fire suppression and to overgrazing, which has decreased the competitive ability of grasses and reduced the amount of fine fuel. While young plants are susceptible to fire, dense mature stands often have inadequate fuel to carry fire.

What ecological role does creosote bush play in the northeastern Mohave Desert? Is it a natural dominant

species of a desert shrub community, or an invader on sites that used to contain a much higher percentage of native grasses and forbs? What native species occur in association with creosote bush on these sites and how well are they adapted to fire?

## SONORAN DESERT

### Trigo Mountains Wilderness, Yuma District

The 30,300-acre Trigo Mountains Wilderness is located about 25 miles north of Yuma, Arizona. The Wilderness includes 14 miles of the Trigo Mountain ridgeline, characterized by sawtooth ridges and steep-sided canyons and is heavily dissected by washes. Vegetation cover is sparse because sites are dry and rocky. Low fuel loading and high fuel viscontinuity have prevented fire from playing a significant role in the development and maintenance of these ecosystems.

### Eagletail Mountains Wilderness, Phoenix District

The 100,600-acre Eagletail Mountains Wilderness is about 65 miles west of Phoenix, Arizona. The Wilderness includes 15 miles of the Eagletail Mountains ridgeline and Courthouse Rock to the north, Cemetery Ridge to the south, and a large desert plain area between the two ridgelines. Any surface disturbance of the stony desert pavement can permit establishment of herbaceous vegetation that can carry a fire.

## DESERT GRASSLAND

### Upper Burro Creek Wilderness, Phoenix District

The 27,440-acre Burro Creek Wilderness is located 60 miles southeast of Kingman, Arizona. The Wilderness preserves an expanse of basalt mesas and the desert grassland found on their rolling upland surfaces. This desert grassland is dominated by sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.), big galleta (*Hilaria rigida* [Thurb.] Benth.), and three awn (*Aristida* sp.). Dry lightning occurs in this area. Because vegetative cover is fairly continuous, it can be assumed that naturally ignited fires used to occur. Fire-caused mortality of these grass species has been observed, but the plant community has recovered. This moderate degree of plant adaptation to fire suggests that fire may have been fairly infrequent.

If it is accepted that naturally ignited fires used to occur in this grassland Wilderness, then a management decision must be made about reintroducing fire. Is this area large enough with adequate barriers to fire spread that some use of prescribed natural fire is possible? Are management ignitions necessary because of constraints to prescribed natural fire? If prescribed burning is required to maintain a natural vegetative character, how often should this area be burned and what weather and moisture conditions are optimal?

## DESERT RIPARIAN

### Needle's Eye Wilderness Area, Phoenix District

The 8,760-acre Needle's Eye Wilderness is located about 20 miles southeast of Globe, Arizona. The Mescal Mountains trend northwest across the center of the area, forming a spectacular striped dip-slope of Paleozoic limestone over 2,500 feet high. Slicing through this range is the Gila River, which enters three canyon segments with 1,000-foot walls known as the Needle's Eye. A deep, entangled riparian zone covers the narrow river channel. Several small slickrock canyons bisect the area and wind to the Gila River.

### Aravaipa Canyon Wilderness, Safford District

The 19,410-acre Aravaipa Canyon Wilderness is 50 miles northeast of Tucson, Arizona. The Wilderness includes the 11-mile-long Aravaipa Canyon. Within the 1,000-foot canyon walls, desert bighorn sheep (*Ovis canadensis* Nelsoni), seven species of native desert fish, and over 200 species of birds live among shady cottonwoods (*Populus* spp.) along the perennial waters of Aravaipa Creek.

Desert riparian ecosystems provide some of the greatest plant and animal diversity in the National Wilderness Preservation System. Not only are these areas critical for the survival of local wildlife species, they provide important habitat for migrating birds. Fire is not a common occurrence in these riparian ecosystems. In some valleys, fire can be carried into the riparian community from the desert grassland above by rolling firebrands. Although many riparian plant species can re-establish after fire, recovery of the vegetative structure may take a long time. Some apparent adaptations to fire may have evolved in response to frequent flooding. Has fire or flooding played the primary role in rejuvenation of mature riparian vegetation? How should we manage a fire that may impact one of these rare riparian habitats?

## FOREST

### Mount Logan Wilderness Area, Arizona Strip District

The 14,650-acre Mount Logan Wilderness is located 50 miles southeast of St. George, Utah, adjacent to Grand Canyon National Park. This has been an area of volcanic activity in recent geologic times. It includes basalt ledges, and a large, colorful, naturally eroded amphitheater known as Hells Hole. Vegetation is dominated by ponderosa pine (*Pinus ponderosa* Lawson) forest and pinyon-juniper woodlands.

Fire exclusion had been a policy for over 100 years within the Mount Logan Wilderness. As a result, in ponderosa pine stands, tree density is much greater, dead woody fuel loadings are much higher, and litter and duff layers are extremely thick. Areas of ponderosa pine were logged many years ago and thinned in the mid-1970's before the Wilderness was designated. Slash from the thinning compounds the fuel problem. A wildfire would have the potential to kill all overstory trees.

A decision has been made to manage activity fuels within this Wilderness. Manual piling and winter burning of thinning slash, in combination with broadcast burning, is the desired treatment. Several low-intensity, low-severity broadcast burns are required to reduce the amount of woody fuels and duff to a level where prescribed natural fire can be allowed to burn.

## SUMMARY

The BLM Wilderness Program is presently in a period of transition. Suitability inventories and studies have been completed and recommendations for Wilderness designation have been made. Wilderness management and fire plans have been completed for a small number of Wilderness Areas and plans are under development for others. The issues outlined above must be addressed in the planning process in order to select the most appropriate fire management strategies for the ecosystems found in BLM Wilderness Areas.

# Light Hand Tactics for Wilderness Wildfire Suppression

**Francis Mohr**
**Bill Moody**

The change in the mid-1970's from fire control to fire management added a new perspective to the role of both the land manager and the firefighter regarding fire suppression activity. The objective of putting the fire "dead-out" by a certain time was replaced by the need to make unique decisions with each fire start, to consider the land and resource objectives, and to decide the appropriate suppression response and tactics, resulting in minimum costs and resource damage.

Traditional thinking that the only safe fire is a fire without a trace of smoke is no longer valid. In many Wilderness or National Park wildfires, implementation of the appropriate suppression response means managing fire with time as opposed to against time. This change in thinking and way of doing business involves not just the firefighter, but all levels of management as well.

Fire management challenges the manager and firefighter to select and implement fire lining and mop-up tactics commensurate with the fire's potential or existing behavior, yet leaving minimal or no adverse environmental or resource impact. Unfortunately, many suppression tactics practiced in the past are still imprinted upon the landscape. As land stewards, this is what we need to avoid.

A pocket-sized guide has been published that identifies lower impact tactics to be practiced during fire lining, mop-up, helispot construction and spike camp activities. It includes rehabilitation techniques for fire suppression-caused impacts. This guide is intended to serve as a checklist for the wilderness manager and for all levels of a fire incident team organization. Copies can be obtained by writing to Francis Mohr, Wallowa-Whitman National Forest, P.O. Box 907, Baker City, OR 97814, or by calling him at (503) 523-1261.

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# Post-Fire Regeneration of Black Cherry and Chokecherry in a Southern Ontario Oak Savanna

**Brian E. Morber**
**Kiyoko Miyanishi**

Controlled burning has been instituted as a means of opening up the understory canopy and maintaining the oak savanna community at Pinery Provincial Park in southern Ontario, Canada (Tegler 1986). However, previous studies on post-fire responses of hardwoods have indicated that fire can enhance tree seedling establishment by stimulating germination, improving seedbed conditions through the reduction of litter and exposure of bare mineral soil, and reduction of competing herbaceous and shrubby vegetation (Went and others 1952; Swank 1958; Ahlgren and Ahlgren 1960; Rouse 1986). Temporary post-fire reduction of competition for moisture and nutrients by herbs and shrubs could also increase tree seedling survivorship (Harrington 1991). Furthermore, fire stimulates stump or root-crown sprouting which would result in increasing rather than decreasing understory stem density (Auclair and Cottam 1971; Axelrod and Irving 1978). Such potential post-fire responses of hardwood trees bring into question the effectiveness of low-intensity burns as a management strategy for opening up the tree canopy. Therefore, the purpose of this study was to examine post-fire sprout and seedling regeneration of black cherry (*Prunus serotina*) and chokecherry (*P. virginiana*) which dominate the understory of this temperate oak savanna.

To examine post-fire sprout and seedling regeneration, two sites were selected which were similar in density and basal area of canopy trees (Table 1) and were dominated by black and white oak. The density and basal area of black cherry trees were also similar between the two sites. Chokecherry does not grow to tree size and was therefore not represented in the upper canopy. Site 1 experienced a wildfire in autumn 1980 and Site 2 was fire-free for at least 33 years prior to being subjected to a controlled burn in the spring of 1990.

The similarity between sites allowed some comparisons in 1988 of sprout regeneration in an unburned community (Site 2) and a community 8 years after a wildfire (Site 1) by examining the density, size, and growth form of saplings. The 1990 controlled burn in Site 2 also allowed a direct study of post-fire sprout and seedling regeneration before and after the fire. Both species sprout from root crowns when topkilled.

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## SPROUT REGENERATION

In 1988, Site 1, which was burned 8 years previously, had a significantly higher density of saplings than Site 2, which had been fire-free for at least 33 years (Table 2). The data on sapling size, age, and growth form summarized in Table 2 support the conclusion that the high density of saplings in Site 2 resulted from the 1980 wildfire. Saplings of both species had a significantly lower mean height in Site 1 than in Site 2. The variability in heights, compared with a variance ratio test, was also significantly less in Site 1 than in Site 2. The ages of sapling-sized stems of chokecherry indicated that the stems in Site 1 arose immediately following the 1980 fire, while those in Site 2 were significantly older. Sapling stems in Site 2 were both significantly older and more variable in age. In addition, the higher proportion of multiple-stemmed plants and the significantly greater number of stems per plant in Site 1 support the idea that most of the saplings at this site originated as either sapling or seedling sprouts following the 1980 wildfire.

Sprout regeneration by saplings following the April 1990 burn in Site 2 was virtually 100% for black cherry and chokecherry plants that were topkilled by the fire. No plants of tree size were topkilled. Mean DBH of the topkilled stems sampled was 2.9 cm for black cherry and 2.7 cm for chokecherry (Table 3). The number of sprouts per plant ranged from 1 to 29 in black cherry and from 1 to 15 in chokecherry. By August 1990, four months after the burn when these sprouts were measured, the height of the tallest sprout on each plant ranged from 17 to 209 cm in black cherry and from 11 to 150 cm in chokecherry. While

**Table 1**—Summary of tree density, basal area and growth form in the two study sites in 1988. Other species include black oak, white oak, red pine, and chinquapin oak. Values in parentheses give percentage of total

| Tree characteristics | Site 1 | Site 2 |
|---|---|---|
| Density (#/ha) | | |
| Black cherry | 25 (6.8%) | 38 (9.5%) |
| Other | 340 (93.2%) | 361 (90.5%) |
| Total | 365 | 399 |
| Basal Area ($cm^2/m^2$) | | |
| Black cherry | 0.32 (1.5%) | 0.36 (1.9%) |
| Other | 21.42 (99.5%) | 18.04 (98.1%) |
| Total | 21.74 | 18.40 |
| Percent Multiple-Stemmed | 41% | 18% |

**Table 2**—Summary of sapling data collected in 1988 for the two study sites. Values in parentheses give percentage of total. Standard Error is abbreviated SE

| Tree characteristics | Site 1 | Site 2 |
|---|---|---|
| Density (#/ha) | | |
| Black cherry | 168 (13.4%) | 101 (12.7%) |
| Chokecherry | 1058 (84.2%) | 397 (50.0%) |
| Other | 31 (2.4%) | 299 (37.3%) |
| Total | 1257 | 794 |
| Percent multiple-stemmed | | |
| Black cherry | 69% | 13% |
| Chokecherry | 52% | 19% |
| Mean number of stems per plant ± SE | | |
| Black cherry | 2.2 ± 0.5 | 1.0 ± 0 |
| Chokecherry | 1.7 ± 0.1 | 1.1 ± 0.04 |
| Mean height (cm) ± SE | | |
| Black cherry | 178 ± 29 | 329 ± 46 |
| Chokecherry | 170 ± 5 | 301 ± 15 |
| Mean age (years) ± SE | | |
| Chokecherry | 8 ± 0.1 | 23 ± 1.8 |

**Table 3**—Summary of data on sprouts of black cherry and chokecherry in August 1990 following a burn in April 1990. All values are means ± standard error

| Sprouts | Species: Black cherry | Species: Chokecherry |
|---|---|---|
| Sample size | 60 | 53 |
| Dbh of dead stem (cm) | 2.9 ± 0.28 | 2.7 ± 0.17 |
| # sprouts/plant | 10 ± 0.8 | 6 ± 0.4 |
| Ht of tallest sprout (cm) | 116 ± 6.8 | 95 ± 3.9 |
| Correlation with DBH of | | |
| # sprouts | 0.21 ($p > 0.05$) | 0.20 ($p > 0.05$) |
| Ht of tallest sprout | 0.73 ($p < 0.0001$) | 0.59 ($p < 0.0001$) |

the number of sprouts was not significantly correlated with DBH of the original stem, the height of the tallest sprout on each plant was highly significantly correlated with DBH for both species (table 3).

## SEEDLING REGENERATION

Table 4 shows the effect of fire on the population of established (more than 1 year old) seedlings of both species. The density of established chokecherry seedlings did not change significantly from 1988 to 1991, either without (Site 1) or with (Site 2) a burn. While the density of established black cherry seedlings did not change in the unburned site (Site 1) over this period, it decreased significantly following the 1990 controlled burn in Site 2. These results suggest a greater fire-tolerance of established chokecherry seedlings compared to black cherry. Table 4 also gives the density of seedlings of both species emerging in each of the 3 years (seedlings less than 1 year old). Neither species showed any significant decrease or increase in germination as a result of the 1990 controlled burn.

In 1990 cherry seeds were collected from 49 litter and soil samples taken from within 20 by 15 cm quadrats in each site. The soil samples were from two depths (0-3 cm and 3-6 cm). Seeds were collected prior to fruit maturation and therefore did not include the current year's crop. There were no seeds in the litter samples from Site 1, although the highest density of cherry seeds was found in the litter samples from Site 2 (12.2/sq m). We found 5.4 and 0.7 seeds/sq m from the two depths respectively in Site 1, and 2.0 and 0.7 seeds/sq m from the two depths in Site 2. These seed quantities are much lower than those reported for black cherry in other mixed forest sites (Marquis 1975; Olmsted and Curtis 1947). Furthermore, despite the reported longevity of black cherry seeds in the forest floor (Wendel 1972), none of the seeds collected

**Table 4**—Mean density (# plants/sq m) of seedlings of black cherry and chokecherry in Sites 1 and 2. Site 2 was burned in spring 1990. Seedling counts for all years were done in the summer

| Site | Species | Year: 1988 | Year: 1990 | Year: 1991 | |
|---|---|---|---|---|---|
| Established (>1 year): | | | | | |
| Site 1 | Black cherry | 0.84 | 1.49 | 1.29 | $p > 0.05$ |
| | Chokecherry | 2.01 | 1.59 | 2.61 | $p > 0.05$ |
| Site 2 | Black cherry | 1.94 | 1.00 | 0.35 | $p < 0.05$ |
| | Chokecherry | 0.93 | 0.61 | 0.55 | $p > 0.05$ |
| Current (<1 year): | | | | | |
| Site 1 | Black cherry | 0.09 | 0.04 | 0.04 | $p > 0.05$ |
| | Chokecherry | 0.07 | 0.06 | 0.14 | $p > 0.05$ |
| Site 2 | Black cherry | 0.39 | 0.16 | 0.18 | $p > 0.05$ |
| | Chokecherry | 0.21 | 0.06 | 0.33 | $p > 0.05$ |

could be germinated in the lab. Therefore, the soil seedbank appears to play little or no role in post-fire regeneration of black cherry or chokecherry in this oak savanna.

## CONCLUSIONS

Both black cherry and chokecherry sprouted prolifically from topkilled plants following both a controlled spring burn and an autumn wildfire. Such sprouting resulted in stands of multiple-stemmed plants with uniformly sized and uniformly aged stems. While a controlled spring burn decreased the density of established black cherry seedlings, it had no effect on chokecherry seedlings, which appear to be very fire tolerant. There was no indication of a fire-stimulated increase in seedling emergence of either species. Post-fire seedling emergence was concluded to be largely dependent on post-fire seed production or seed influx from unburned adjacent areas, since there was no significant viable seedbank of either species in the soil. The post-fire response of black cherry and chokecherry appears to be an increase in sapling-sized stem density due to sprout regeneration with fires having little or no effect on seedling regeneration. However, even in the absence of increased recruitment to the populations from seedlings, subcanopy closure may be enhanced by the rapid growth of multiple sprouts from topkilled seedlings and saplings. Therefore, if the objective of burning a savanna is to decrease woody vegetation and open the above-ground canopy to allow the maintenance of light-demanding herbaceous savanna species, the fire-enhanced regeneration of canopy and subcanopy species such as black cherry and chokecherry by sprouting could present a problem, especially at places like Pinery where a large reserve of saplings and seedlings exists for advance regeneration.

## ACKNOWLEDGMENTS

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# Whitebark Pine and Fire Suppression in Small Wilderness Areas

**Michael P. Murray**
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Whitebark pine (*Pinus albicaulis*) occurs in the mountainous regions of western North America. Relatively little attention has been given to this conifer by researchers due to its low potential for timber production. Recently, ecologists have been noting the importance of whitebark pine to high elevation ecosystems. Its seeds are a valuable food source for grizzly bears (*Ursus arctos horibilis*) (Mattson and others 1992), black bears (*Ursus americanus*) (Mattson and Jonkel 1990), Clark's nutcrackers (*Nucifraga columbiana*) (Tomback and others 1990), red squirrels (*Tamiasciurus hudsonicus*) (Reinhart and Mattson 1990), and other mammals, birds, and insects. These trees provide roosting habitat for blue grouse (*Dendragapus obcurus*) in addition to nest cavities for mountain bluebirds (*Sialia currucoides*) (Kendall and Arno 1990) and northern flickers (*Colaptes auratus*). Whitebark pine influences moisture and energy cycling as well as temperatures on microsites (Hann 1990). Trees help stabilize snow and soil (Arno and Hoff 1989). They provide attractive scenery, shelter, and fuel for recreationists (Cole 1990). The presence of whitebark pine facilitates understory communities unlike those found in adjacent open sites.

Along with knowledge of the many values of whitebark pine, the rapid decline of populations has also become apparent to researchers in recent years. An introduced blister rust (*Cronartium ribicola*) has killed significant numbers of trees as have the native mountain pine beetle (*Dendroctonus ponderosae*).

Most recently, whitebark pine has been observed as declining at rates considered to be unprecedented in canopy cover within stands composed of other tree species (Arno and others 1993; Keane and Arno 1993; Morgan and Bunting 1990). This widespread successional replacement has resulted in the loss of whitebark pine in seral stands. This dramatic decline is suspected to be the direct result of fire suppression (Arno 1986). Investigation of this decline is crucial in determining the rate and geographical extent of the problem. This study attempts to enhance our understanding of the relationships of fire suppression and whitebark pine.

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The Clark's nutcracker plays an important role in the regeneration of whitebark pine (Hutchins and Lanner 1982; Tomback 1978, 1982). These jay-like birds have adapted sturdy, long beaks which enable them to pry open cones to reach seeds. Nutcrackers store seeds in a sublingual pouch below their beak while foraging in the crowns of trees. An individual bird may cache as many as 129,000 seeds in a season (Hutchins 1990). After extracting seeds, nutcrackers will fly from a few meters to as far as 22 km (14 miles) (Tomback 1978) to bury seeds in a variety of sites including forest floors, rocky terrain, meadows, and burned land. Seeds are frequently cached in groups of 1 to 15 seeds (Tomback 1986). Seeds often germinate due to conducive soil conditions and the failure of birds to retrieve most caches (Tomback 1978; Hutchins and Lanner 1982).

## FIRE AND SUPPRESSION

### Site Improvement

The importance of burned sites to Clark's nutcrackers has just recently been documented (Sund 1988; Tomback 1986; Tomback and others 1990). Tomback (1986) observed these birds caching seeds in a recently burned stand of krummholz whitebark pine in Yosemite National Park. Four years after this fire, seedling density was 2.5 times higher (.02 seedlings/m$^2$) on the burned site compared to an adjacent unburned stand. Tomback and others (1990) found similar densities in the Bitterroot Range after fire.

Successful whitebark pine establishment in burned areas has been attributed to several factors. Nutcrackers can transport seeds and bury them in the center of large burned sites. Wind-disseminated seeds of associated trees have less transport range. Nutcracker planting of seeds within large burns offers whitebark seedlings a spatial advantage. In addition, whitebark pine are more hardy on exposed microsites, outcompeting associated trees (Arno and Hammerly 1984; Arno and Hoff 1989).

### Successional Relationships

The effects of fire suppression may be most apparent in the successional status of stands recently studied. The pine is characteristically long lived and has historically maintained significant cover in mixed stands (Arno 1986). In these stands where it is seral to subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*),

whitebark pine regeneration has been perpetuated by periodic fires (Arno 1986). In the absence of fire, subalpine fir and Engelmann spruce, which are less fire-resistant, are able to outcompete whitebark pine in mixed stands (Arno 1986). It is likely that whitebark pine abundance has dramatically declined in forest stands of mixed species since the introduction of fire suppression (Arno 1986; Keane and others 1990; Morgan and Bunting 1990).

Forests where whitebark pine is seral have historically experienced mean fire intervals of 50 to 300 years (Arno 1980). Since the early 1900's, the United States and Canadian Governments have actively suppressed forest fires throughout the range of whitebark pine (West 1991; White 1985). Although wilderness areas include a considerable acreage of whitebark pine, fires in most of this acreage in the United States continue to be suppressed (Philpot 1985; Twiss 1993, this proceedings). It is likely that fire suppression is even more intensive on a majority of the land that whitebark pine occurs on. Outside of Yellowstone National Park, only a few thousand hectares of seral whitebark pine forests have burned since 1970 (Arno 1986).

Fire suppression may also facilitate mountain pine beetle epidemics. Suppression has created extensive areas of mature lodgepole pine (Kendall and Arno 1990). These stands often attract large populations of beetles, which may then attack adjacent whitebark pine stands. Whitebark pine climax stands comprised of many old trees may be especially susceptible to beetles (Kendall and Arno 1990).

Due to the paucity of knowledge on whitebark pine communities, investigation of successional status in a variety of areas is greatly needed to assess possible effects of fire suppression (Arno 1986). Some research has been conducted in large wilderness areas where fire exclusion has not been complete (Agee and Kertis 1987; Mattson and Reinhart 1990; Renkin and Despain 1992; Romme 1982; Tomback 1986). Especially lacking are insights of fire history and successional status in small wilderness and roadless areas.

Large reserves tend to be more conducive for the viability of most native species. This argument has commonly been applied to faunal populations (Gilpin 1987; Wilcove 1986). Attention to floral species, especially in temperate North America, is lacking.

# BACKGROUND

## Study Area

We have chosen the West Big Hole region along the Montana-Idaho border as our study area. This area has a significant amount of roadless land, but is still a small reserve when compared to many roadless lands where whitebark pine occurs. In addition to the small size of the reserve, it is geographically isolated from other whitebark pine populations on the landscape. Located in the narrow Beaverhead Range, this naturally fragmented mountain mass may have unique historical patterns of fire.

Stretching along the Continental Divide from Big Hole Pass south to Goldstone Pass, our study area is a subrange of the Bitterroots. The West Big Hole study area is flanked on the east by the Big Hole Valley and on the west by the Lemhi and Salmon valleys. Foreman and Wolke (1992) defined approximately 86,000 ha (215,000 acres) of this area to be roadless. Where roads occur, they generally follow the bottoms of drainages toward the Divide. Between Big Hole and Goldstone Pass, no roads cross the Divide. Rather, they terminate as cul-de-sacs at various elevations.

In addition to the biogeographical isolation of this region, there is an additional opportunity to investigate the possible effects of established roads on fire and whitebark pine occurrence.

Our research objectives are to:

- Account for the historical size, frequency, and patterns of fire
- Assess the current abundance and successional status of whitebark pine communities
- Estimate past and present occurrence of whitebark pine and predict future status.

# METHODS

Field data we will acquire can be divided into two general categories, fire history, and community and stand characterization. We will employ different sampling techniques for each category.

Investigation of fire history will include review of historical records and examination of aerial photographs. We will collect field data from tree cores and cross-sections. In addition, we will incorporate community and stand characteristics, such as stand structure, in determining fire history.

The ECODATA system developed by the Forest Service (USFS 1992) will be used. Where necessary we will modify, substitute, or add to the existing ECODATA procedures to better serve research objectives. Circular 0.4-ha (0.1-acre) plots will be established in conditions that represent the surrounding stand. Examination of blister rust incidence will help in predicting its influence on future mortality of whitebark pine.

We will examine selected roaded and unroaded drainages as well as the upper reaches of tree growth near the crest of the Divide. Drainages will be selected to represent general vegetation character and fire history of all drainages of the same type (roaded or unroaded).

In selecting plot sites the topography, vegetation, and disturbance conditions must closely resemble conditions apparent within the remaining portion of the selected stand. Data to be collected include: species composition, habitat parameters, tree age structure, and blister rust infection rate. A global positioning system (gps) rover unit will be used to record accurate locational records for each plot.

# SUMMARY

Whitebark pine is an ecologically important tree species in the high mountains of the West. Fire has historically been important in sustaining seral populations of this conifer. It is likely that whitebark pine is declining due to fire suppression. Because of the paucity of knowledge on

whitebark pine communities, investigation of successional status in a variety of areas is greatly needed to assess possible effects of fire suppression.

The West Big Hole area represents a small wilderness area that is biogeographically isolated. Insight into fire history and whitebark pine status in the West Big Hole will be valuable in forming management recommendations for similar landscapes. Such insight may be especially useful in managing for future abundance of whitebark pine, which is critical to the well-being of these high mountain ecosystems.

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# Effects of Fire Severity and Climate on Ring-Width Growth of Giant Sequoia After Burning

**Linda S. Mutch**
**Thomas W. Swetnam**

Although fire has been recognized for several decades as a significant ecological force in giant sequoia (*Sequoiadendron giganteum*)-mixed conifer forests (Hartesveldt 1964, Biswell 1967, Hartesveldt and Harvey 1967, Kilgore and Biswell 1971, Kilgore 1973, Harvey and others 1980), little is known about the growth response of giant sequoia to different types of fire and post-fire climate conditions. As early as 1964, Hartesveldt observed that after two fires (1862 and 1889) in the Mariposa Grove in Yosemite National Park, "...more than one-half of the cored trees showed an increase in the middle of the 1860's, and several showed an increase immediately after the fire of 1889." He attributed this increased ring growth to temporarily reduced competition from associated trees that were damaged or killed by the fires, resulting in improved soil moisture conditions for the more fire-resistant sequoias. Harvey and his colleagues (1980) also observed that radial growth increased in some giant sequoias following fire and other manipulation of understory vegetation. Growth releases frequently followed fire scars on the sequoia cross-sections analyzed during reconstruction of giant sequoia fire regimes (Swetnam 1992). The most striking example was a tremendous growth increase in many sequoias following an A.D. 1297 fire in Mountain Home State Forest. This release was probably the result of a high intensity fire that killed many competing trees and increased nutrient, water and light availability for the survivors (Stephenson and others 1991, Swetnam 1992).

A goal of this study was to determine if fire severity could be quantified in terms of post-fire sequoia tree-ring widths. Quantification of fire severity by the magnitude and duration of post-fire sequoia growth increases may provide an objective basis for estimating past fire severities from observations of sequoia cross-sections collected while developing fire history chronologies. In addition to examining effects of fire severity on sequoia radial growth response, we examined some general relationships between climate, fire, and post-fire sequoia growth. We analyzed the effect of severe foliage damage on post-fire growth in the Partin Burn. For all burns and control sites, we also made categorical observations of sequoia seedling establishment around each adult sequoia sampled to investigate the effects of fire severity and post-fire climate conditions on seedling establishment and success.

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## SITE DESCRIPTION

The study sites are located in the Giant Forest of Sequoia National Park and in the Redwood Mountain Grove and Grant Grove of Kings Canyon National Park, California. Elevations of these groves range from 1,650 to 2,100 m. In addition to giant sequoia, dominant trees are primarily white fir (*Abies concolor*) red fir (*Abies magnifica*), sugar pine (*Pinus lambertiana*), ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*) and incense-cedar (*Calocedrus decurrens*).

Mean annual precipitation is 108.2 cm at Giant Forest and 105.8 cm at Grant Grove. Most precipitation occurs in the form of snow during the four winter months from December through March. Summers are relatively dry, with about 30 cm of rainfall occurring from June through September.

The study included seven burn sites and four control sites. The burns were all prescribed burns conducted by the National Park Service. The dates of burns in Giant Forest were 1979 (Moro Burn), 1981 (Circle Burn), 1982 (Cattle Burn), 1984 (Class Burn), and 1985 (Broken Arrow Burn). The Partin Burn in the Redwood Mountain Grove occurred in 1977, and the Grant Burn in 1980. The control sites had not burned for at least 50 years and had characteristics as similar as possible to burn sites.

## METHODS

### Field Methods

A minimum of 50 large sequoias (greater than 250 cm basal diameter) were randomly selected for sampling on each burn and control site (except where burns were small and contained less than 50 large sequoias). Two increment cores were taken in 1991 or 1992 from each tree. Cores were taken from opposite sides of the tree and as far away as possible from fire scars.

Observable fire-related impacts to surrounding trees were used to estimate fire severity. All non-sequoia trees within a radius equal to twice the area of the subject tree canopy were considered. We selected one of the following categories to describe these impacts:

0) No evident fire.
1) Light surface fire; no evidence of trees killed.
2) Light to moderate severity; some seedlings and/or saplings killed; charring on bark of living trees.
3) Moderate severity; most small trees and <50% of subcanopy trees killed; charring on bark of living trees.

4) High severity; >50% of the subcanopy trees killed or damaged; high charring and some crown damage on trees, but <50% killed.
5) Very high severity; most subcanopy trees killed and >50% of canopy trees killed.
6) Fire too old and little evidence of fire impact remains.

In the same area around each subject tree, sequoia seedling establishment was categorized as:

0) No seedlings.
1) Scattered or few seedlings.
2) Pockets of seedlings.
3) Continuous, dense seedling growth.

We measured basal area scarred, estimated scar height and height of bark charring, and estimated percent new scarring. We also observed crown condition of each tree and measured the slope and aspect.

## Lab Methods

Cores were surfaced and crossdated according to standard techniques (Douglass 1941, Stokes and Smiley 1968, Swetnam and others 1985). All the cores were measured for the period 1920 to 1990. The program COFECHA (Holmes 1983) was used to check the tree-ring dating and measurements for each site. The ring-width series were then standardized using a new program written by Richard Holmes called EXTRAP (Holmes 1993), which allows the user to choose a pre-disturbance period used for fitting an expected growth curve. We used the period 1920 to 1970 as the curve-fitting period for all sites. The EXTRAP program fit a negative exponential or a trend line to each series, whichever best fit the actual individual series' growth trend. It then extrapolated the curve into the post-disturbance (1971 to 1990) period. Each measured series' ring-width value was then divided by the expected growth value to produce a set of indices. We averaged these core indices into tree indices and the tree indices into a site chronology for each site. Standardization removed growth trend due to changing age and geometry of the trees and also scaled all the series to mean values of 1.00 so that trees with larger rings did not dominate slow-growing trees with smaller rings in the analyses (Fritts 1976).

# ANALYSES AND RESULTS

## Burn and Control Site Comparisons

We conducted T-tests between each burn and its respective control site to determine if mean growth was significantly different for either the pre- or post-burn periods. For each burn, we used the total number of years in the post-burn period to determine the length of the tested pre- and post-burn periods. The number of years analyzed for each period ranges from five years in the 1985 Broken Arrow Burn to 13 years in the 1977 Partin Burn. Tree-ring time series are autocorrelated (Fritts 1976). Hence, individual years cannot be treated as completely independent observations, a key assumption of the T-test. We found significant autocorrelation in a few of the time periods analyzed. To account for autocorrelation, we reduced the effective sample size (by reducing the degrees of freedom) when determining probability levels.

Mean growth was not significantly different in the pre-burn periods between burn and control sites (Table 1). In the post-burn period, mean growth was significantly higher in burn sites than control sites for four out of seven burns. The three exceptions—the Moro, Cattle, and Grant burns—were low to moderate severity fires that did not result in large post-fire increases.

Examination of the ring-width indices reveals the different growth responses between burns and between the burn and control sites (Figure 1). It is evident that a

**Table 1**—T-test results for differences in pre- and post-burn mean growth between burn and control sites. Asterisks indicate significantly different means within each comparison ($P<0.05$). Giant Forest is abbreviated by GW; Redwood Mountain Grove is abbreviated by RW.

| Site | Sample (# years) | Pre-burn mean growth | Post-burn mean growth |
|---|---|---|---|
| Moro Burn | 11 | 1.05 | 1.51 |
| GF Control | 11 | 1.07 | 1.32 |
| Circle Burn | 9 | 1.04 | 1.67 * |
| GF Control | 9 | 1.05 | 1.37 * |
| Cattle Burn | 7 | 0.93 | 1.39 |
| GF Control | 7 | 1.02 | 1.39 |
| Class Burn | 6 | 1.30 | 2.06 * |
| GF Control | 6 | 1.12 | 1.41 * |
| Broken Arrow | 5 | 1.32 | 1.85 * |
| GF Control | 5 | 1.22 | 1.40 * |
| Partin Burn | 13 | 1.15 | 1.90 * |
| RW Control | 13 | 1.16 | 1.28 * |
| Grant Burn | 10 | 1.08 | 1.54 |
| Grant Control | 10 | 1.15 | 1.42 |

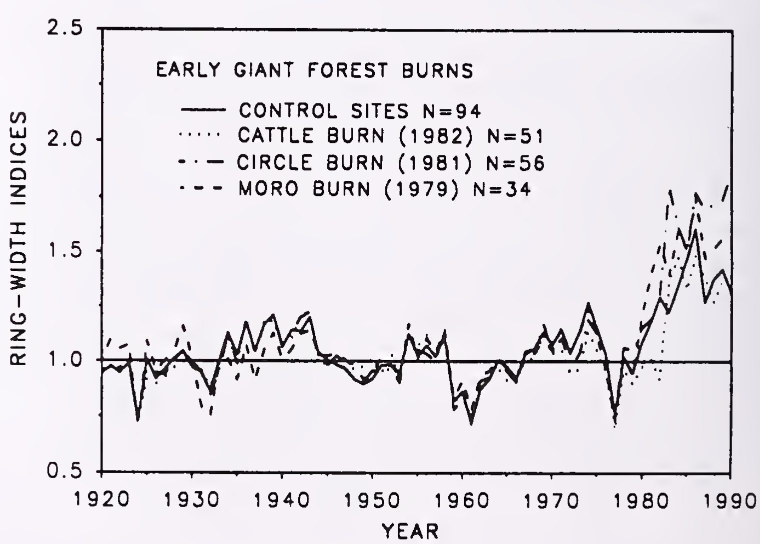


**Figure 1**—Standardized mean ring-width indices for the Moro, Circle, and Cattle burns and for the two Giant Forest control sites (which were averaged together to produce one set of control indices).

growth increase began at all sites in the late 1970's. Relatively wet climatic conditions in the early 1980's (particularly the El Nino event of 1982-1983) probably played an important role in the observed trend of increased growth at all sites through this period. Greater variability in growth patterns between sites in the 1980's was probably due to different timing of burns and subsequent growth increases in the sites. Note that the higher severity 1981 Circle Burn, which also preceded by one year the wet winter of 1982-1983, had the largest and longest sustained growth increase, while the lower severity 1982 Cattle Burn had a growth increase similar to that of the unburned control sites.

Both mid-1980's Giant Forest burns (Class and Broken Arrow) had a dramatic growth increase in the post-burn periods relative to the control site indices (Figure 2). The control sites began to decline in growth by 1987, coinciding with drought conditions that persisted through the late 1980's. In these burn sites, it appears that fire moderated the effects of drought on sequoia growth.

## Growth Responses to Different Fire Severities

We compared mean ring-width growth between trees sustaining different fire severities. Within each site, trees were grouped into low, moderate, and high fire severity categories. "Low severity" included categories 1 and 2 (listed under the field methods section), "moderate severity" included category 3, and "high severity" included categories 4 and 5. For the Partin Burn, which had a large number of trees in both the 4 and 5 categories, these two groups were treated as "high" and "very high" severity.

For the Kings Canyon sites, burn indices were separated into the different fire severity levels estimated on the two burns (Figure 3). The Partin Burn included moderate, high, and very high severity levels, while the Grant Burn only had low and moderate fire severity. All three severity groups in the Partin Burn had significantly higher growth in the post-burn period than did the Redwood Mountain control site. The moderate and high severity groups had a very similar growth pattern at this site, while the very high severity group showed a slightly delayed growth increase that declined more rapidly in the late 1980's. This difference was due to the extensive foliage damage sustained by three trees in the very high severity group. This foliage damage resulted in missing rings in these trees for several years after the fire, and also probably reduced their drought tolerance in the late 1980's. However, mean growth for this group was still significantly higher than that of the control site for the post-burn period (Tukey's Standardized Range Test, df=48, P<0.05).

The Grant Burn indices indicate that the low severity group had a growth pattern essentially identical to that of the control site. This suggests that low severity fire on this site did not reduce competition or increase soil nutrients enough to cause a growth increase above that expected from climatic conditions alone. The moderate severity group showed a more pronounced growth increase, which is significantly higher than that of both the low

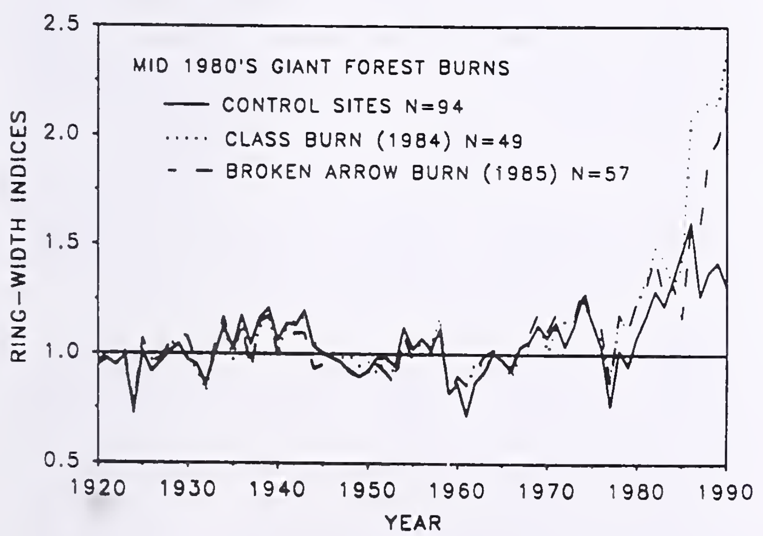


**Figure 2**—Standardized mean ring-width indices for the two mid-1980's Giant Forest burns (Class and Broken Arrow) and the Giant Forest control sites. Both burns had a dramatic growth increase in the post-burn periods relative to the control sites.

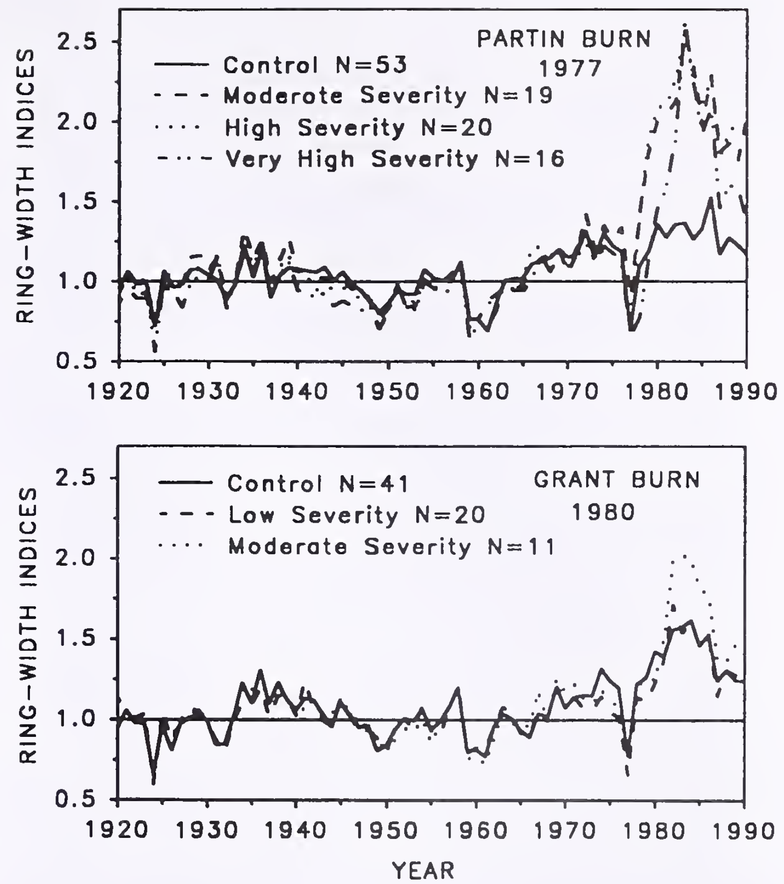


**Figure 3**—Standardized mean ring-width indices for burn and control sites in Kings Canyon National Park. Burn indices were separated into groups of sequoias sustaining different fire severity levels. The Partin Burn included moderate, high, and very high severity fire, while the Grant Burn only had low and moderate severity fire.

severity group and the control site (Tukey's Standardized Range Test, df=27, P<0.05).

## Individual Year Post-Burn Growth

Although mean growth for a post-burn period provides a useful measure for comparing burns to control sites and for comparing the effects of different fire severity levels on tree growth, it obscures the differences in growth responses for individual years between the fire severity categories. In order to examine how different fire severity levels affect growth in different years following a fire and to show the different patterns of growth responses for four fire severity levels, we first subtracted the mean growth of the control site from each burn series for each year analyzed (10 years pre-fire and 10 years post-fire). The result is a set of "difference series" from which effects of climate and site on growth should be removed; the remaining difference is primarily the growth response due to fire effects. A similar approach has been used in the study of the effects of air pollution and defoliation on tree-ring growth (Nash and others 1975, Swetnam and others 1985).

The low severity group is from the Grant Burn; the moderate group includes eight trees from the Grant Burn and eight from the Partin Burn. The high and very high severity groups are both from the Partin Burn. The sample size is 16 trees for each group. From Figure 4, it is apparent that there is very little variation in the difference series in the pre-burn period for any group, due to the fact that the effects of climate on growth have been effectively removed. In the post-burn period, the series become quite different from each other. This is probably due to varying effects of different fire severities.

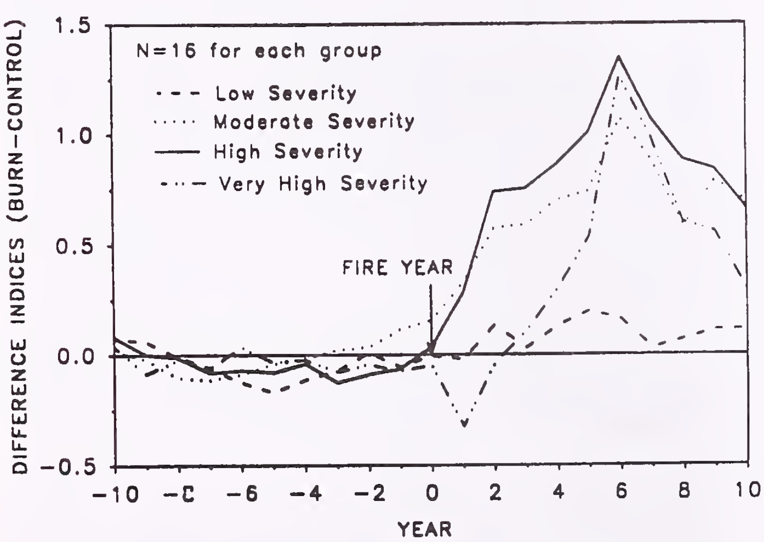


**Figure 4**—Difference indices (burn minus control indices) for sequoias sustaining four different levels of fire severity in the Grant and Partin burns. Subtracting the control indices removes the effects of climate and site on growth; the remaining difference is primarily the growth response to fire.

The trees sustaining low severity fire had almost no growth increase, while the trees sustaining high severity fire had the largest and most sustained growth increase. The trees in the moderate severity group showed a lower growth release peak and declined in growth more rapidly than those in the high severity group. For trees sustaining very high severity fire, including some trees with foliage damage, growth declined in the first years following the fire. This group, on the average, increased in growth during the second through fifth years following the fire and then declined more rapidly than the moderate and high severity groups.

## Broken Arrow

In the mid-1980's, a small area in the Broken Arrow burn in Giant Forest generated public criticism of the prescribed fire program in Sequoia and Kings Canyon National Parks. Relatively high levels of bark char on one group of sequoias raised concern among some visitors about aesthetics and potential harm to giant sequoias resulting from burning. Our analysis of post-fire tree-ring widths indicates that four out of six trees in this group which sustained foliage damage did show ring growth suppressions after the fire. But by the third year after the fire, most of the trees had resumed near-normal growth. During the third to fifth years following the fire, the mean growth of the 20 trees in Broken Arrow that sustained high severity fire was higher than that of trees in the low and moderate severity groups (Figure 5).

Trees sustaining low and moderate severity fire had very similar post-fire growth increases. The trees sustaining high severity fire had low growth in the two years following the burn, but growth increased substantially in years three through five. This is a typical pattern observed in most burn sites with high severity fire.

## Seedling Establishment

Both fire severity and post-fire climatic conditions appear to be important to post-fire sequoia seedling establishment. Table 2 compares sequoia seedling establishment around all adult sequoias sampled in control sites and burn sites, separated into three different fire severity categories (low, moderate, and high). In the control sites, only 4 percent of adult sequoias had surrounding seedling establishment, while in burns, sequoia seedling establishment was greater and generally proportional to fire severity. Seventeen percent of adult sequoias sustaining low severity fire, and 46 percent and 87 percent of adults sustaining moderate and high severity fire, respectively, had surrounding sequoia seedling establishment. The large difference in percent of adults with seedling establishment between these four groups indicates the importance of moderate to high severity fire to sequoia regeneration.

We also compared seedling establishment between two burns that preceded the wet climatic conditions of the early 1980's (Circle and Partin) and two burns that were followed by drought conditions in the mid- to late-1980's (Class and Broken Arrow). All four burns included some moderate and high severity fire. Sixty-six and 76 percent

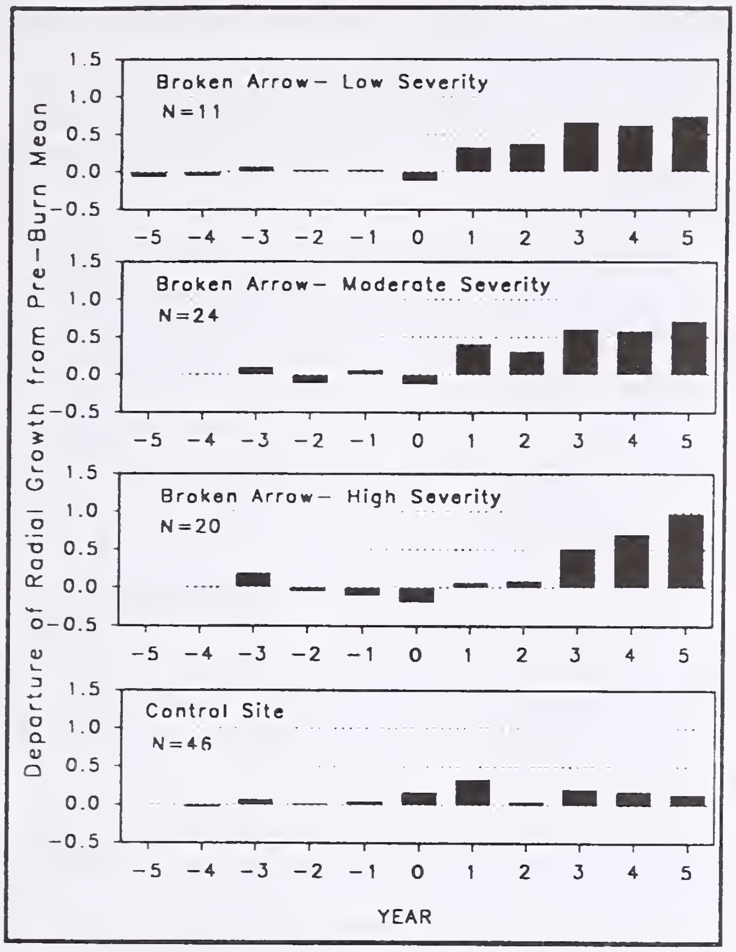


**Figure 5**—Growth for the five-year pre-burn and five-year post-burn periods relative to the pre-burn mean for each severity group in the Broken Arrow Burn and for the control site. In these graphs, year zero is the year of the burn, and growth for each year is graphed relative to its increase above or decrease below the five-year, pre-fire mean.

**Table 2**—Seedling abundance in control and burn sites. The relative frequency of adult sequoias with: (0) no surrounding seedling establishment, (1) a few scattered seedlings, (2) pockets of seedlings, and (3) continuous, dense seedling establishment.

| Seedling categories | Control | Low severity | Moderate severity | High severity |
|---|---|---|---|---|
| | *Percent* | | | |
| 0 | 96 | 83 | 55 | 14 |
| 1 | 4 | 13 | 22 | 23 |
| 2 | 0 | 4 | 22 | 54 |
| 3 | 0 | 0 | 2 | 10 |

of the adult sequoias sampled in the 1981 Circle Burn and the 1977 Partin Burn, respectively, had surrounding seedling establishment. Thirty-six percent of adult sequoias in the 1984 Class Burn and 42 percent in the 1985 Broken Arrow Burn had surrounding seedling establishment. The two burns followed by wet conditions had an overall higher percent of adults with seedling establishment as well as a larger number of seedlings (more adults with clumps of seedlings or continuous seedling cover—categories "2" and "3"). We conclude that sequoia seedling recruitment is most favored by a combination of moderate to high severity fire and wet post-fire climatic conditions.

# DISCUSSION

Prescribed fire generally appears to have positive effects on radial growth of adult giant sequoia trees. Most burns had significantly higher post-fire mean growth than control sites for the same time period. Only three out of seven prescribed burns did not have significantly higher post-fire mean growth than control sites (Cattle, Moro, and Grant burns). The relatively low fire severity of these three burns compared to the others may not have resulted in enough reduction in competition or increase in nutrients to create substantially improved growing conditions in the post-burn period.

Some differences were evident in the growth response patterns between groups of sequoias sustaining low, moderate, high, or very high severity fire. We observed three general growth response patterns—minimal or no increase, associated with low severity fire; immediate, pronounced post-fire growth increase, associated with moderate and high severity fire; and delayed growth increase, associated with very high severity fire where foliage damage occurred. It is possible that these kinds of growth response patterns could be used to infer fire severities of older fires by examining post-fire ring-width patterns associated with known fire dates obtained from fire-scar analysis.

Positive post-fire effects seemed to moderate negative climatic effects on sequoia growth. This is most evident in the Class and Broken Arrow burns, which occurred in the mid-1980's at the onset of drought conditions that persisted through the late 1980's. Both sites showed dramatic post-burn growth increases, while the control sites were declining in growth for most of this dry period. Climate did not appear to have a major effect on the magnitude of post-fire growth responses. Significant growth increases occurred in burns that preceded wet conditions as well as in burns that preceded dry years.

Post-fire climatic conditions were more important to successful seedling establishment, with wet conditions being more favorable than dry conditions to seedling success. Harvey and others (1980) and Stephenson (1994) have also observed that seedling survival is greatest when the first one or two summers following a fire are wet. We found that seedling establishment was proportional to fire severity, with high and very high severity fire resulting in many more sequoia seedlings than low and moderate severity fire. In general, there is a positive relationship between disturbance size or intensity and the availability of resources for plant growth (Canham and Marks 1985). The gaps in the canopy created by more severe fire provide the increased light that the shade-intolerant sequoia seedlings require. Increases in available nutrients, in particular nitrogen, after fires in sequoia-mixed conifer forests (Kilgore 1973, St. John and Rundel 1976, Sackett and others, unpublished results) also probably contribute to rapid early growth of sequoia seedlings, increasing their chances of surviving future fires and outcompeting other

species. Climate and fire regime characteristics (fire size, frequency, and severity) have interacting effects on sequoia seedling establishment and survival. These effects are reflected in the episodic nature of sequoia recruitment over time and space (Stephenson 1994).

## MANAGEMENT IMPLICATIONS

Prescribed fire has positive effects on the radial growth of most adult giant sequoias; however, fire-damaged foliage is an important factor causing brief post-fire growth suppressions. Giant sequoias respond to fire in a variety of ways, including both growth increases and growth suppressions. The growth responses of giant sequoia to prescribed fires are not outside the range of growth responses observed in ring-growth patterns after presettlement fires (Swetnam 1992). This indicates that the prescribed burning in Sequoia and Kings Canyon National Parks has not resulted in "unnatural" growth responses in giant sequoias, even in the more severe burns criticized by some members of the public.

Although the Sequoia and Kings Canyon National Parks prescribed natural fire program does not have the explicit goal of promoting sequoia seedling establishment, the strong relationship between fire severity and numbers of seedlings establishing in the post-burn period suggests that burning plans should be flexible enough to allow (and even encourage) burns with a variety of fire severities. Adult sequoias appear to be well-adapted to sustain as well as benefit from a variety of fire severities, and sequoia regeneration is significant only in areas sustaining moderate, high, or very high severity fire.

## ACKNOWLEDGMENTS

This research was funded by the National Interagency Fire Center in Idaho and the Research Office in Sequoia and Kings Canyon National Parks, California. We would like to thank Tony Caprio for contributing ideas at many stages of this project and Chris Baisan and Peter Brown for helpful discussions. We would also like to thank Bryan Bird and Chad Robinson for their tireless field assistance and Shmuel Burmil, John Rapp, and Bill Dimsdale for patiently measuring many of the tree rings used in these analyses.

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# Prescription for a Wilderness: Isle Royale National Park

**Jack G. Oelfke**

Isle Royale National Park lies in the northwest quarter of Lake Superior, some 15 to 20 miles off the mainland boundaries of Minnesota, U.S.A. and Ontario, Canada (Figure 1). The park contains 572,000 acres, of which 134,000 are land (and heavily forested). The typical fire season extends from May through September.

## EVOLUTION OF THE FIRE MANAGEMENT PROGRAM

The evolution of the Isle Royale program closely parallels the historic fire management philosophy of this country, that of total suppression for much of the century followed by a more enlightened approach of allowing natural fires to burn. At Isle Royale, this change occurred in the mid-1970's. Certainly this sequence is not unique; however, the fact that a large tract of forested wilderness exists in the eastern half of the United States which can support a natural fire program is of significant importance.

Perhaps even more so than the large, remote western parks, accessibility and logistics to points around Isle Royale is difficult and potentially dangerous. There are no roads in the park; access to and around the park is limited to powerboat, canoe/kayak, foot trail, helicopter or float-plane. Much of the shoreline consists of either exposed rocks or shallow-water reefs; boat access is dangerous and

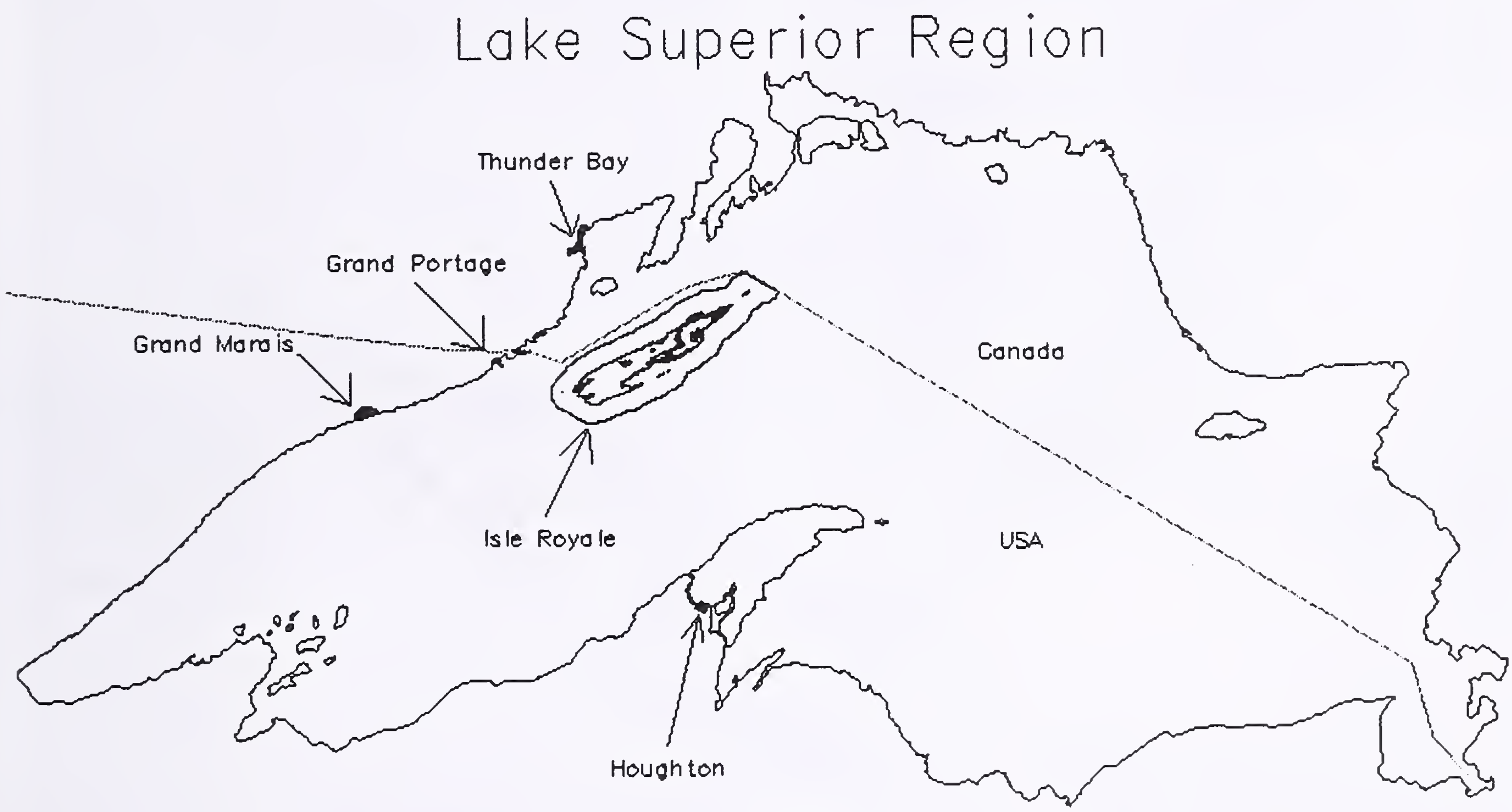


**Figure 1**—Isle Royale National Park, Michigan.

In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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severely limited. Suppression efforts can be costly and logistical support time-consuming; having the authority to allow natural fires to burn, with a small monitoring crew dispatched, makes sense for both economic and ecological reasons.

## THE FIRE ENVIRONMENT

Isle Royale is located within the tension zone between the boreal forest and northern hardwoods. The eastern end of the island is dominated by boreal forest species such as balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), aspen (*Populus tremuloides*), and white birch (*Betula papyrifera*), while the western end reflects the northern hardwood biome—a forest of sugar maple (*Acer saccharum*) and yellow birch (*Betula alleghaniensis*). Interspersed are swamp and wetland forests of black spruce (*Picea mariana*) and white-cedar (*Thuja occidentalis*). Xeric (dry) ridges are occupied by grass and brush, or open stands of red oak (*Quercus rubra*), white pine (*Pinus strobus*), or jack pine (*Pinus banksiana*). The role of fire in influencing the island's vegetation and wildlife is well documented (Hansen and others 1973; Peterson 1977; Janke 1983; Cochrane 1991; Janke 1993); less defined is the pre-Columbian fire regime, although limited paleo-ecological evidence shows a long history of fire (Raymond 1975).

The arrival of moose (*Alces alces andersoni*) to the island in the early 1900's has led to important changes within the forest structure, resulting in a change to the fire environment. Moose have substantially altered both the overstory and understory vegetation communities. In essence, a "spruce-moose savanna" has developed in large areas of the island (Jordan 1977). Within these "savannas" young balsam fir are heavily browsed and cannot grow to canopy size. The understory vegetation was once dominated by Canada yew (*Taxus canadensis*); the moose's fondness for this species has nearly caused its extirpation from the park. Thimbleberry (*Rubus parviflora*) has replaced the yew, and is a much less flammable plant material. The net effects of these moose-induced changes are not yet fully understood, but perhaps a less flammable forest environment has been created.

## IF NOT HERE, THEN WHERE?

Isle Royale National Park is ideal for a prescribed natural fire program. Some 95% of Isle Royale, 127,000 acres, lies within a Prescribed Natural Fire Unit where naturally-ignited fires may be allowed to burn (Fire Management Plan, Isle Royale National Park, 1992) (Figure 2). A Conditional Fire Unit includes "buffer" areas around sensitive locations where under a very conservative prescription we may allow a naturally-ignited fire to burn. A Suppression Unit, which occurs around developed areas, as well as a few cultural and archeological resource

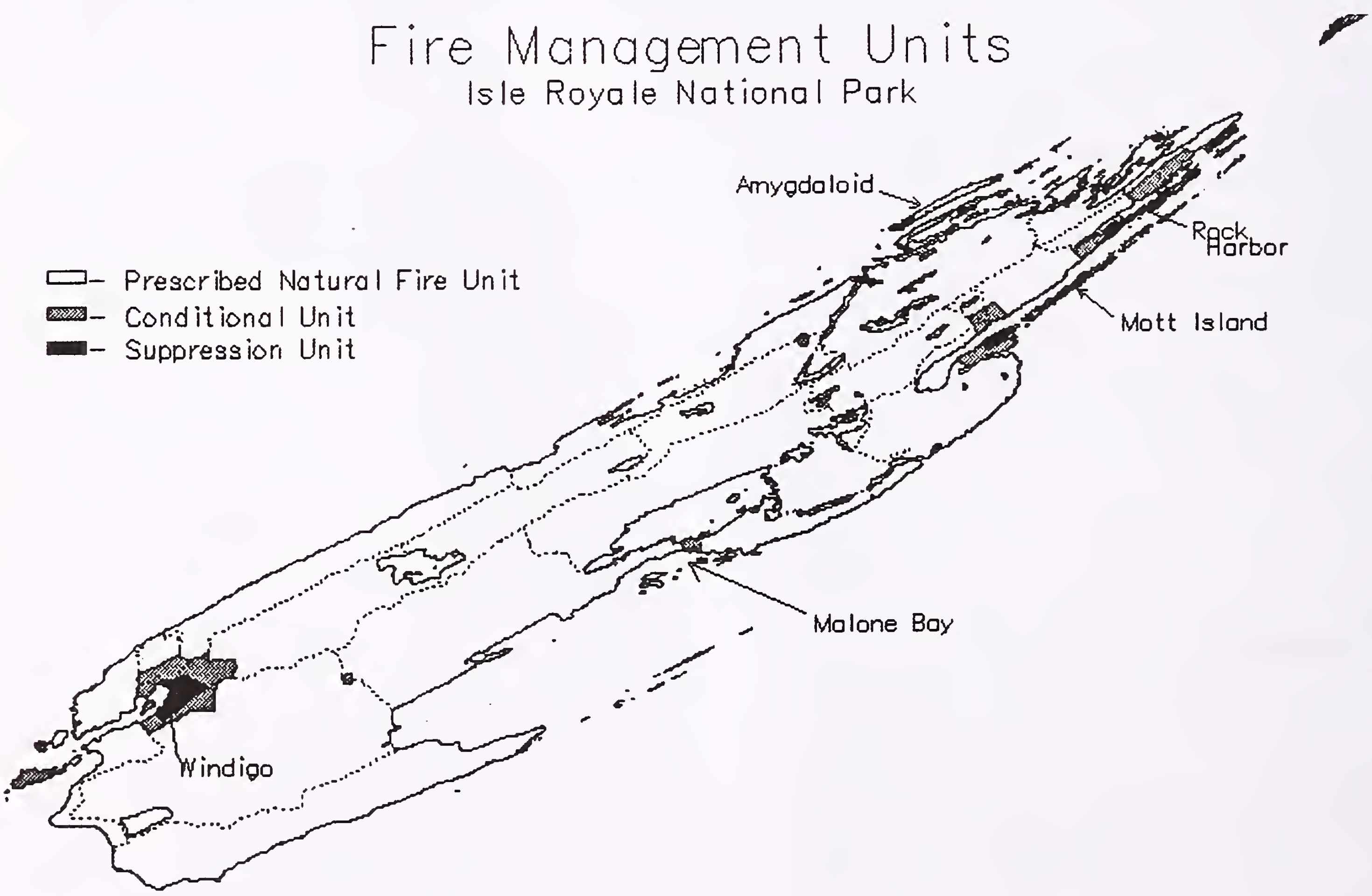


**Figure 2**—Fire Management Units, Isle Royale National Park.

sites, is the only area where the required response to a naturally-ignited fire is one of suppression.

All acreage within the park is owned by the National Park Service—there are no private inholdings other than a few cabins occupied seasonally by "life lessees." These cabins typically occur near the shoreline or on small islands, and impose few constraints on a natural fire program. Our island geography implies no adjacent landowners, thus no conflicts or coordination is required in regard to a prescribed natural fire crossing ownership boundaries. Although there exist some developed areas within the park sensitive to smoke impacts, only one small community on the mainland lies within a 20-mile radius. Smoke impacts should be a minor constraint.

If a prescribed natural fire program cannot succeed on Isle Royale, then, indeed, where might one exist?

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# A Comprehensive System to Monitor 1,000-Hour Fuel Moistures in Yellowstone National Park

**William R. Parkhurst**
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**Lawrence W. Johnson**

The 1988 fires in the Greater Yellowstone Ecosystem posed many questions for wildland fire researchers and managers. Two questions persisted. Are computer-simulated fuel moistures reflective of actual fuel moistures observed in the field? Are the National Fire Danger Rating System (NFDRS) indices associated with a particular area accurate?

Studies in the Greater Yellowstone Ecosystem from 1989 through 1992 suggest the 1,000-hour time-lag analog fuel moistures (1,000-hour) calculated by the NFDRS are not always reflective of the fuel-moistures obtained by field sampling. This is sometimes reflected in unexpected fire behavior. To reconcile conflicts between actual fuel moisture and fire behavior observed in the field and fire behavior and fuel moisture predicted by the NFDRS indices, Yellowstone National Park developed an extensive network of permanent 1,000-hour research sites throughout the park. In 1989, Yellowstone National Park began an effort to systematically collect field data on 1,000-hour fuel moistures and compare them to simulated NFDRS values. This hands-on effort soon expanded to include weather variables, soil and duff moistures, and the moisture of green plants, including conifer needles. The challenge of how to systematically collect, report and analyze fuel-moisture data became quite complex. Methods and techniques monitoring the dryness of field conditions were designed to be repeatable. The data obtained from these methods and techniques allows manual manipulation of the NFDRS indices to more accurately reflect actual field conditions.

## METHODS AND PROCEDURES

Selection of fuel-moisture research sites in the Greater Yellowstone Ecosystem is influenced by fire occurrence, accessibility, proximity to weather stations and management concerns.

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Currently, there are 43 permanent fuel-moisture monitoring sites with over 500 log samples designed to represent 1,000-hour moistures. After the site locations were selected, a dead and downed survey was done using the techniques described by Brown and others (1982). Photopoints were established using methods described by Fischer (1981). A precipitation gauge was placed on each site and emptied during each site visit.

Five sets of green lodgepole pine (*Pinus contorta*) logs were removed from each site. Green logs were used so we could determine exactly how long the samples have been decaying for wood degradation studies. The logs were 4 to 6 inches in diameter and were cut into 2-foot lengths. This was the longest length the dryer could accommodate.

Recognizing the improbability of removing all hygroscopic water by oven-drying without pyrolyzing the wood, the logs were dried at 45 °C until the weight loss was less than 0.2% in a 2-hour period. This is the constant density of the sample. It is assumed to be the weight of the log at 0% fuel-moisture. If green logs are dried at temperatures exceeding 45 °C, there is a strong tendency for large cracks to develop.

After the logs were dried to constant density, the ends were coated with clear polyurethane varnish. A tint of stain was added to the varnish to enhance the visibility of the logs that were treated in mass. It is easy to miss a log when 75 to 100 logs are processed simultaneously. The purpose of the varnish is to force the moisture out the sides of the sample when it is in place at the study site. Exposed ends greatly enhance the movement of water by greater capillary exposure.

The samples were identified using round aluminum tags affixed to one end with a 3-inch aluminum nail. The number of the sample, date of processing, site code, and constant density were recorded in a specialized computer program developed by Wichita State University.

The samples were returned to their respective sites. The logs were placed on a wood rack 12 inches over a prepared duff bed and oriented north. An arrow was inscribed in one end to ensure the sample was returned to the same position after it was handled, avoiding an unnatural drying effect.

The samples were weighed twice each week from May through October with Ohaus 6000 scales, to the nearest gram. The logs were allowed to be in the field for one year after processing to hydraulically stabilize with the site before being included in the data base.

The percent fuel-moisture is calculated by the formula:

$$\frac{\text{WET WEIGHT} - \text{DRY WEIGHT} \times 100}{\text{DRY WEIGHT}}$$

The fuel moisture calculations are input manually into the NFDRS. The fuel moistures are compared to the NFDRS indices estimated for the nearest fire weather reporting station. The actual fuel-moistures are often significantly different than the NFDRS estimates. See figures 1 and 2.

The samples can be weighed during the winter under snowpack to document the moisture influence from the snow. A profile is cut vertically from the snow surface to the ground beside the log rack. The ends of the logs are located and are individually tapped with a hammer. This separates the logs from the snow and the rack with minimal impact on the snow canopy. Surface snow is brushed off and the logs are weighed. The excavated area beside the log rack is then refilled with snow. The information gained is useful for predicting fuel moistures early in the spring. In 1992, Yellowstone used these fuel moistures with other information to apply for fire severity money. The fuel moistures may also be input into the NFDRS to start fire weather reporting stations at the beginning of the fire season instead of using indices estimated by the NFDRS.

At the end of the second year, some of the logs were returned to the laboratory and redried. The difference between the new and original constant densities is an indicator of wood degradation. It is usually site-specific, although some areas are very similar. The remaining logs were left in the field and will be retrieved for degradation purposes in later years. Each year five more logs are placed on each site.

When the logs were weighed during the fire season, samples of soil, duff, litter, grass, shrub, 1-, 10-, and 100-hour fuels, and of conifer needles were also gathered and dried. The dryness of the samples collected was determined using thermogravimetric methods. The information from some of the sites was sent to the Intermountain Fire Sciences Laboratory in Missoula, MT, for inclusion in the greenness factor study using the Normalized Difference Vegetation Index.

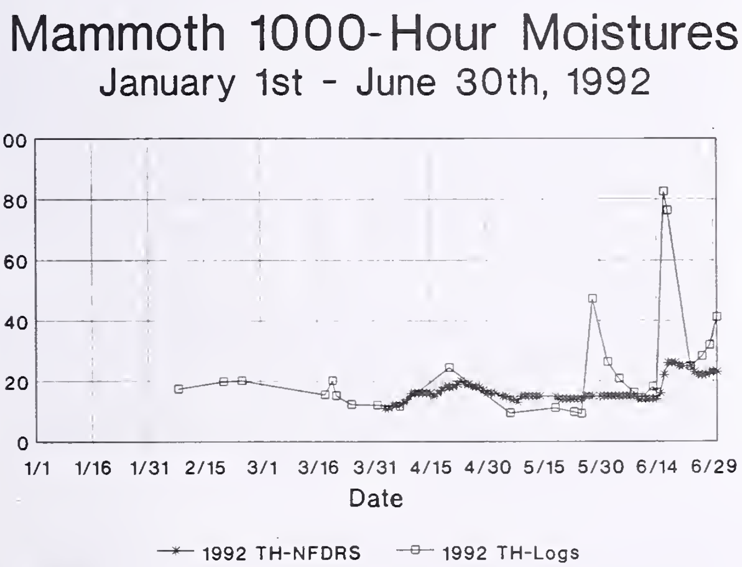
## DISCUSSION AND RESULTS

The 1,000-hour field sites may be used as part of a long-term management strategy or to periodically check fuel moistures obtained by sampling against the NFDRS fuel moisture estimates. Other classes of fuels may be examined for a more comprehensive documentation of site dryness. The fuel moisture of the 1,000-hour logs may be examined periodically under snowpack to determine the effect of the snow on fuel moisture of the samples.

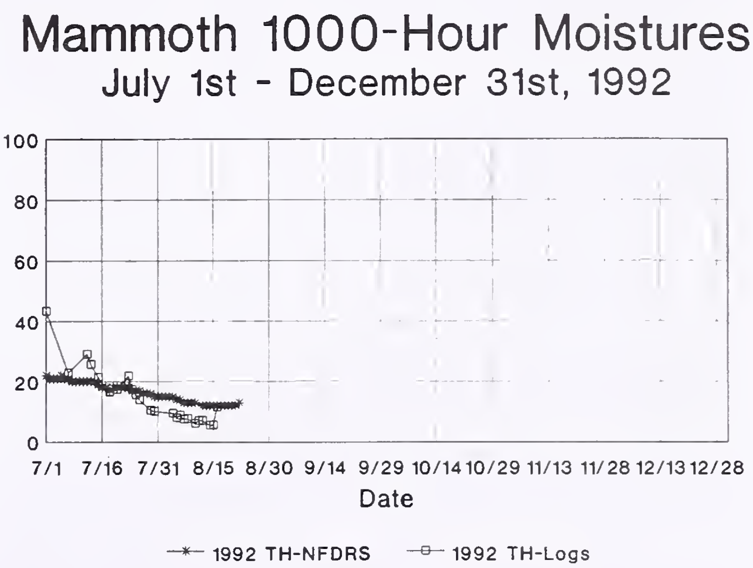
The actual 1,000-hour measurements obtained in the field during the fire season may significantly vary from the NFDRS estimate. Yellowstone National Park has 43 active sites which compare these values. After sufficient data are obtained, some of the sites may track closely with others and will be closed.

We have not gathered data for a long enough period to determine wood degradation curves. It is important to begin with samples that are green to document this process.

These studies should be well planned to leave the least possible site impact. Gathering samples of vegetation and soil components is destructive. The cumulative impacts can be significant in a short time, especially when samples

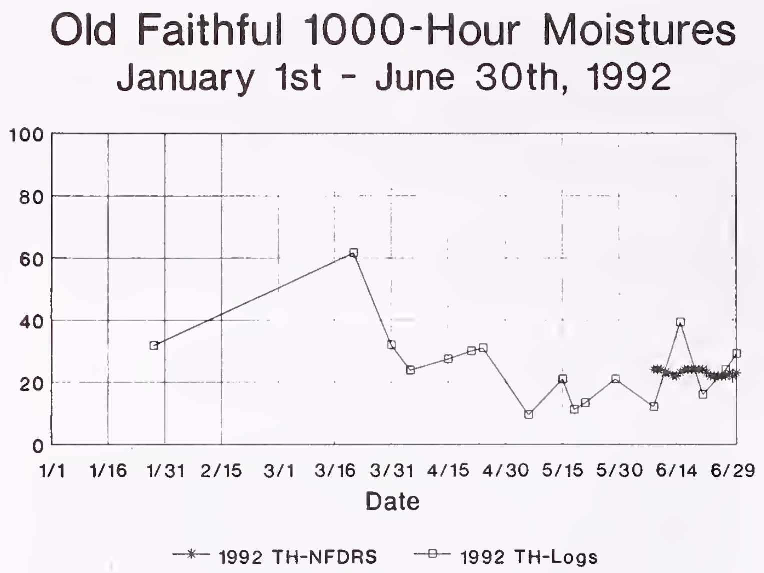



Graph 1A

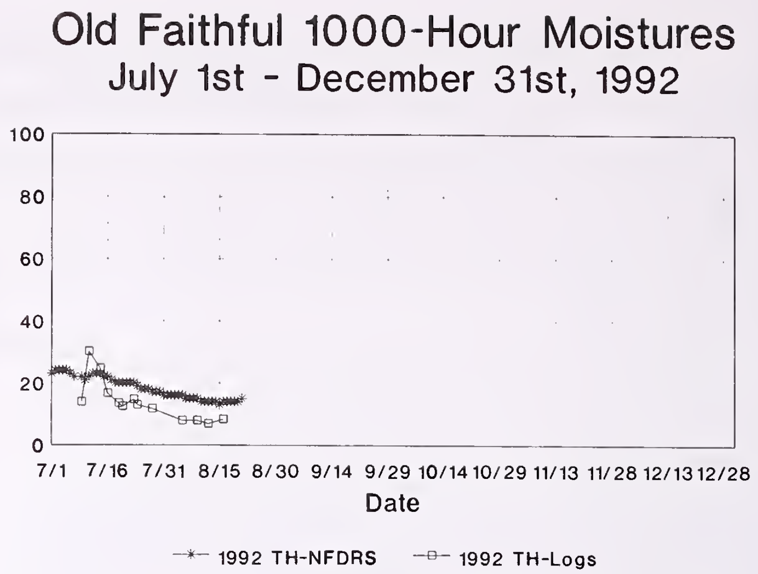



Graph 1B

**Figure 1**—Measured 1,000-hour (TH) fuel moistures at Mammoth Hot Springs, Yellowstone National Park, compared to National Fire Danger Rating System (NFDRS) indices.




Graph 2A




Graph 2B

**Figure 2**—Measured 1,000-hour (TH) fuel moistures at Old Faithful, Yellowstone National Park, compared to National Fire Danger Rating System (NFDRS) indices.

are taken twice a week. This should be considered in the planning of these studies. The sites should not be placed in proximity to game trails or in areas frequented by wildlife.

Collecting this data is labor intensive. The Embedded Systems Project in the Department of Electrical Engineering at Wichita State University has developed a sensor to remotely sense the moisture content of the 10-hour fuel class. It is important to expand the application and development of these sensors into 1-, 100-, and 1,000-hour fuel classes. A prototype of a 1,000-hour sensor has been developed; we have also experimented with sensors to detect the moisture of green vegetation.

The 1-, 10-, 100-, and 1,000-hour fuel classes might be represented accurately by an electronic sensor made from an array of synthetic materials created in the last few years. Efforts to develop a synthetic sensor in the past suffered from a lack of available materials. Wichita State University has developed technology to monitor moisture in very dry materials. A synthetic sensor would probably decrease costs of maintenance and ensure that all reporting stations around the country are obtaining moistures in a more consistent manner. Wood materials, such as the standard 10-hour time-lag analog fuel-moisture sticks have a degree of inherent variability in the quality of the manufacturing process and of the wood. Remotely controlled electronic sensors reduce errors associated with manually weighing and recording these materials. The development of electronic sensors is a cost-effective way to monitor some of the parameters studied to predict wildland fire danger and moisture changes in the plant communities.

Agencies need to establish standards for fuel-moisture studies. The data is of limited use to the research or planning community if there is no agreement on techniques to collect the data and perform statistical treatments. Members on the planning committee dealing with the NFDRS need to be in agreement with these procedures and take an active part of the review process.

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# A System to Remotely Sense Moisture Levels in 10-Hour Time-Lag Fuels

**William R. Parkhurst**
**Richard R. Bahr**
**Lawrence W. Johnson**

A calculation of the moisture content in the 10-hour time-lag analog fuel class is input into the National Fire Danger Rating System (NFDRS). The dryness of the 10-hour fuels affects the energy release component and the burning index.

There are three generally accepted methods to ascertain 10-hour fuel moistures. These methods are weighing standard 10-hour time-lag analog sticks, drying 10-hour field samples and using the Handar 439-A fuel temperature and humidity instrument on weather data collection platforms to estimate the 10-hour moisture.

Each method has inherent problems. Weighing 10-hour fuel sticks is labor-intensive. The accuracy of standard beam scales used to weigh the fuel sticks is sometimes questionable. The precision of the measurement is further limited by user skill. Quality and age of the wood stock used in the manufacturing of the sticks influences the final product. There can be significant variation of hydraulic dynamics in different sets of sticks. Figure 1 plots the high and low fuel-moistures (stick weights) observed between five sets of sticks over a five-week period as they responded to the environment. The average variation was 2 to 3%.

Gathering field samples is also labor-intensive and requires a drying apparatus. The skill of the samplers varies. The techniques used to process the samples are not universally accepted. Computational errors are common, especially when dealing with tare weights (when the weight of the container is removed for a net weight of the sample).

The Handar 439-A fuel-moisture sensor consists of a thermistor and humidity analyzer embedded in a wood sheath. The central processing unit in the weather station converts the sensor's estimation of the humidity and temperature inside the sheath into a percent fuel-moisture through an algorithm. Test data for the 439-A sensor taken from the Handar manual suggests significant, random errors. The random errors are not correctable by manipulating the algorithm used by Handar to estimate the fuel moisture from relative humidity and temperature inside the sensor. The maintenance cost of these sensors ranges from \$200 to \$300 for each station per year. Some of the reporting stations are in remote locations and require considerable effort and cost to access.

The Embedded Systems Project (ESP) has designed an electronic sensor to accurately and consistently monitor the fuel-moisture and temperature of 10-hour fuels. The ESP fuel-moisture sensor is interfaced into weather data collection platforms manufactured by Campbell Scientific, Solus and Handar. The sensor is a direct, plug-in replacement for the 439-A fuel-moisture sensor on Handar platforms.

## METHODS AND PROCEDURES

Five standard 10-hour sticks and an ESP sensor were placed at the Mammoth weather station in Yellowstone National Park, Wyoming. The sticks and sensor were allowed seven days to stabilize with the environment. The sensor and fuel sticks were placed on a rack, 12 inches over a prepared duff bed and oriented to the north. The fuel sticks were inscribed with an arrow to ensure the sticks are returned to the same position after being handled.

After the seven day stabilization period, the sticks were weighed during daylight hours for three months, using

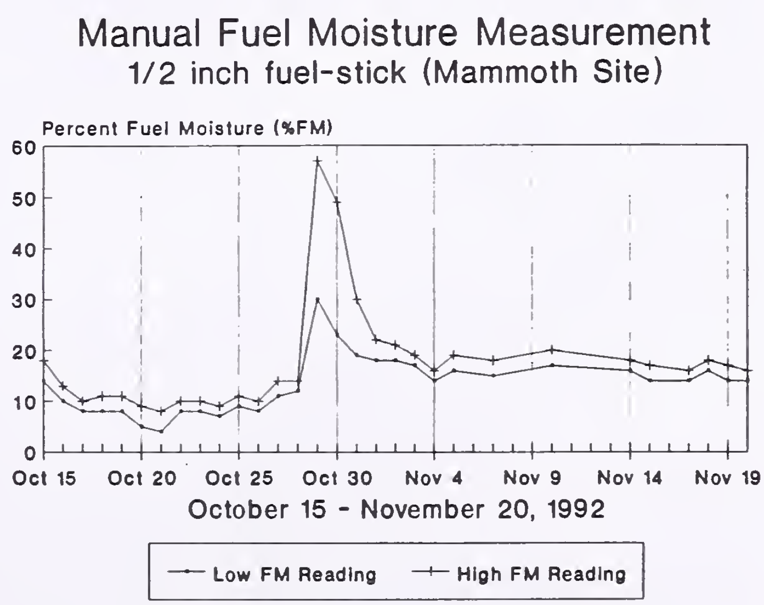


**Figure 1**—High and low fuel moistures of fire fuel sticks over a 5-week period.

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Ohaus scales (Model CT-1200); at the same time the sensor obtained a reading. The sticks' weights were rounded to the nearest gram. That number was then rounded to the nearest single percent fuel-moisture. The high and low weights were discarded. The remaining three stick weights were averaged to represent the percent fuel-moisture of the population. These averaged weights were used as control points and plotted against the data obtained from the fuel-moisture sensor. We have obtained over 1,500 data points using this technique; about 1,000 points are summarized on figures 2 and 3. Figure 2 is data collected from the ESP sensor controlled by the Handar 540 weather data collection platform. Figure 3 plots data obtained when a ESP sensor is controlled by a Solus WeatherNet weather data collection platform. The ESP sensor readings in figures 2 and 3 are plotted against actual stick weights as described above. Figure 4 illustrates fuel temperature variation over the data collection period.

To ensure that the wood portion of the ESP probe could be manufactured consistently, several probes were soaked in water to the point of fiber saturation (about 25% fuel moisture). The probes were allowed to dry at room temperature and humidity. The drying curves of each probe were plotted on figure 5. The probes show a slight variation in their ability to absorb water; they differ in weight when removed from the water. This is predicted given the range of variation in fuel stick moistures when water levels exceed the fiber saturation point of the wood that is seen in figures 2 and 3. The probes then dry along similar curves and finish drying at between 6 and 8% fuel moisture. The range of variation from start to finish in the drying curves of the wood probe was well within the range of variability we have documented in the 10-hour sticks. Graph 5 also demonstrates that the probes react to the environment as a 10-hour sensor, drying 66% in about 10 hours.

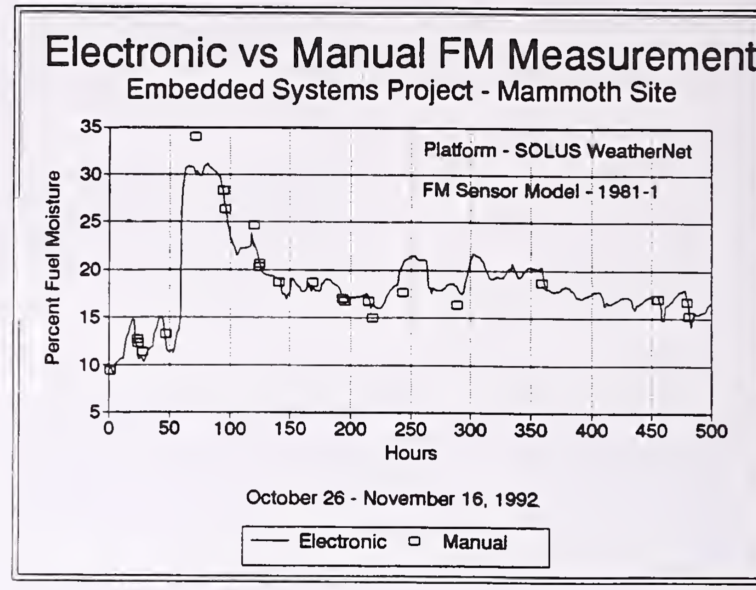


**Figure 3**—Comparison of fuel moistures measured electronically by an Embedded Systems Project Sensor and measured manually by weighing fuel moisture sticks. The electronic sensor was controlled by a Solus WeatherNet weather data collection platform.

## RESULTS AND DISCUSSION

The range of fuel moistures examined was 4 to 30%. The wood and air temperatures ranged between 15 and 85 °F. The ESP sensor was within ± 0.5% in the fuel moisture range of 4 to 20%. From 20 to 30% the sensor was within ± 1%. The accuracy is 10% of the final reading.

The data points from the ESP fuel-moisture sensors were always within the individual variation range of the

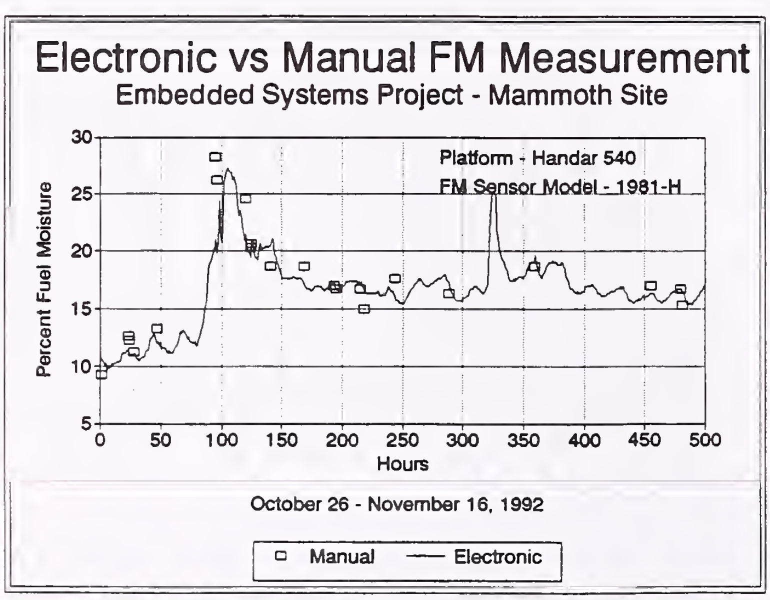


**Figure 2**—Comparison of fuel moistures measured electronically by an Embedded Systems Project Sensor and measured manually by weighing fuel moisture sticks. The electronic sensor was controlled by the Handar 540 weather data collection platform.

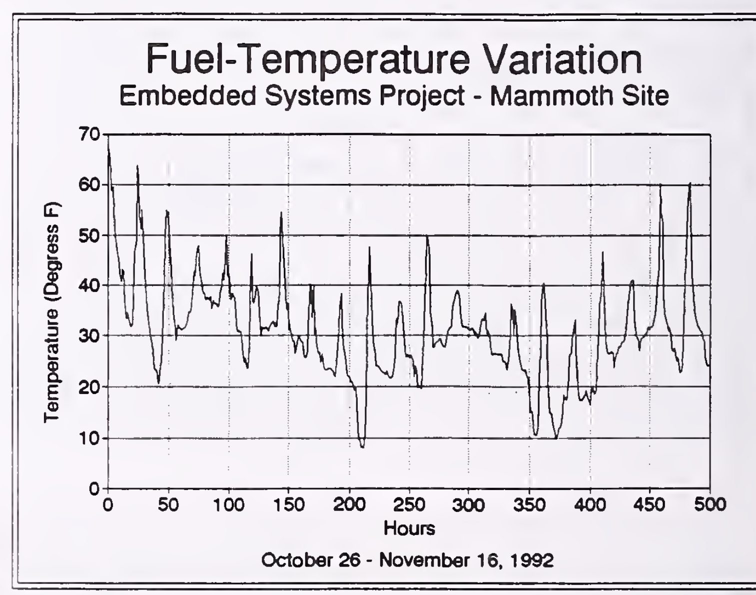


**Figure 4**—Variation in fuel temperatures during the period when fuel moistures measured electronically were compared with those measured manually.

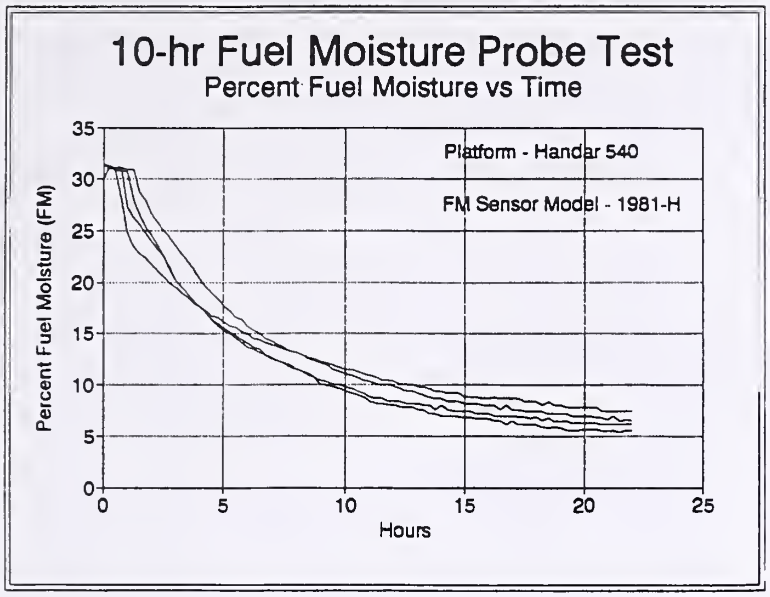


**Figure 5**—The drying curves of four different fuel moisture probes soaked in water until they were saturated.

standard 10-hour sticks. By design, the sensor is more accurate at fuel-moistures under 10%. Above the fiber saturation point, there is a significant variation among the fuel sticks; absorption of water and drying of the wood can be irregular. This is reflected in the sensor readings. This is also observed in the drying curves plotted from the probe comparison in figure 4.

The ESP probe uses permanently embedded electrodes in a three inch section of dowel removed from a standard 10-hour fuel moisture stick. Permanently embedded electrodes have historically given erratic readings in wood due to an accumulation of electrolytes around the probes over time. This is especially noticeable when large direct current (DC) potentials are applied to the same probe over time. The ESP sensor uses a very small DC voltage; concentration of electrolytes around the probes has not been observed.

The probe is affected by wood degradation. The rate of degradation is site specific. After several months of using the same probe at different locations in Yellowstone National Park, there were no significant differences in readings when the seasoned probe was compared with a newly manufactured probe. We would expect more wood degradation on the sensor if it was left in the field for more than a year or used in a more humid environment.

Several sets of sticks were discarded to obtain five sets that tracked weather events similarly. This demonstrates variability within the control. The readings from the sensor were never outside this range of variability when the moisture content of the wood was below the point of fiber saturation.

We used electronic scales to weigh the sticks to the nearest gram in an exclosure shielded from the wind. We would expect more variability when using the scale apparatus that is provided at the standard weather stations.

We examined the time-lag characteristics of the ESP sensor without the luxury of environmental chamber. The sensor performed as a 10-hour fuel, drying 66% in about 10-hours.

Uniform techniques are necessary for the ESP sensor and the control population to accurately reflect weather events. The distance of the sticks and sensor over the duff bed, proximity to obstructions and orientation in the environment are particularly important.

The probe can be made of species other than ponderosa pine. Since the electrical, chemical and physical properties of each species is different, a new wood characterization table is required for each species.

If funding is available, the Embedded Systems Project intends to create a single sensor that can be programmed to monitor 1-, 10-, 100-, and 1,000-hour fuel classes. The sensor will probably be designed of synthetic material. The user will be able to maintain it. A portable version that can be used without a weather station, will also be developed.

# Restoring Fire to Giant Sequoia Groves: What Have We Learned in 25 Years?

**David J. Parsons**

Giant sequoia (*Sequoiadendron giganteum*) ecosystems are well adapted to periodic fire. Fire suppression following the 1890 creation of Sequoia and General Grant (later to become Kings Canyon) National Parks represents the longest fire-free interval in the sequoia groves of the Sierra Nevada for at least the last several thousand years (Swetnam 1993). Recognition of the effects of fire suppression on inhibiting sequoia reproduction, increasing hazardous fuel accumulations, and generally changing forest structure led to the implementation in 1968 of a prescribed burning program in the sequoia-mixed conifer forests of the two Parks (Bancroft and others 1985). This program has been accompanied by an extensive research effort designed to improve both our understanding of the historical role of fire and the effects of varying fire frequencies and intensities on ecosystem properties (Parsons 1990).

## PROGRAM HISTORY

Based on an understanding that fire suppression was changing the character of the giant sequoia forest, early program goals and burn objectives emphasized reducing accumulated ground fuels, thinning shade tolerant understory trees, and encouraging sequoia reproduction. Burns were generally characterized by strip headfires of relatively uniform intensity. As more was learned about the natural role of fire in sequoia forests, including the importance of patchy, variable intensity fires, these goals, objectives, and techniques were modified to emphasize the restoration of fire as a "natural" process (Bancroft and others 1985).

Prescribed fire technology has now advanced to the point where fire managers can create almost any desired pattern of forest structure or function. However, the definition of what is desired has continued to be a problem. One of the greatest challenges to the prescribed fire program has been in defining what is "natural" (Kilgore 1985). For example, should any fire ignited by lightning be considered natural, or only if it is burning in "natural" fuel conditions? In the giant sequoia groves it is recognized that the fire suppression era has created fuel and forest structure conditions that have not occurred in the last several millennia. They would not have occurred today, had fires been permitted to continue to burn.

When we speak of restoring natural fire to the sequoia groves, we mean the restoration of fire burning at similar frequencies and intensities and with similar effects as would have occurred if modern man had never come on the scene. This requires an understanding of past vegetation and fire regimes as well as the effects of varying fire frequencies and intensities.

Since the prescribed burning program was initiated in 1968, 3,643 of the 10,810 acres (33.7%) of giant sequoia in Sequoia and Kings Canyon have been burned by management-ignited fires (Fig. 1). The average of 146 acres (1.35%) burned per year translates to a fire return interval of 74 years. An additional 764 acres have been burned in prescribed natural fires during this time (raising the average to 176 acres or a return interval of 61 years). This contrasts with a mean fire interval of 4.1 years (for the period A.D. 500 to 1900) that has been documented from fire scars for the Circle Meadow area of Giant Forest (Swetnam and others 1992). Approximately 2,637 acres (24.4% of the groves) per year would need to be burned to achieve a 4.1 year mean fire interval for the sequoia groves of the two Parks.

## WHAT HAVE WE LEARNED?

Over two decades of research and monitoring associated with the sequoia-mixed conifer forest prescribed fire program has documented numerous fire effects. Early findings included understanding the importance of heat in opening sequoia cones and releasing seeds, exposing mineral soil to

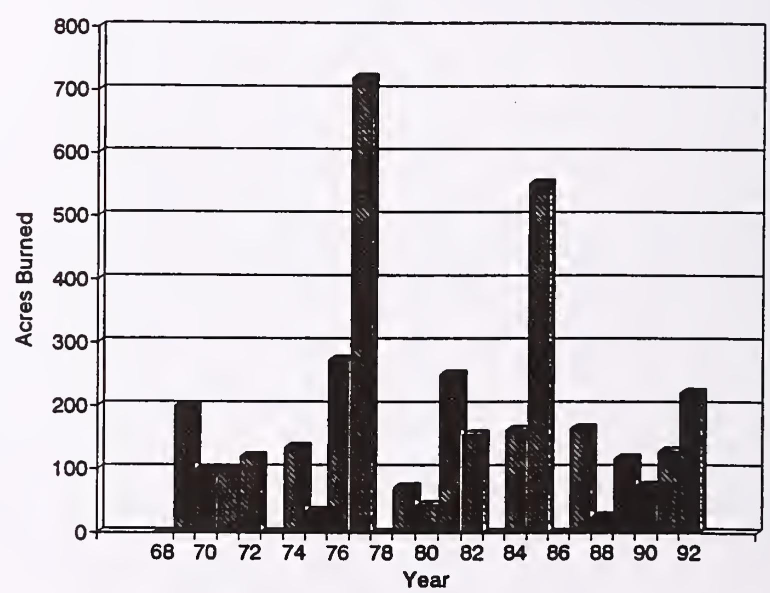


Figure 1—Total acreage of giant sequoia forest burned each year by management ignited fires in Sequoia and Kings Canyon National Parks. In addition, 150 acres were burned in 1986 and 614 in 1991 in prescribed natural fires.

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prepare seedbeds for sequoia seedling establishment, reducing flammable ground fuels, thinning of shade-tolerant understory trees, and stimulating shrub and hardwood sprouting (Kilgore 1972). An increased survival of sequoia seedlings following especially hot fires (Harvey and Shellhammer 1991) and the release of usable forms of nitrogen have also been documented.

Paleoecological studies of sequoia forests have confirmed a striking interdependence between vegetation, climate and fire over the past several thousand years. Pollen and plant macrofossils from meadow sediments document a significant shift in species dominance in current sequoia groves, including a marked increase in giant sequoia over the past 10,000 years, a time period characterized by increasingly moist conditions (Anderson 1990). This high temporal variability in species composition and structure suggests a dynamic community that is responsive to shifts in climate and disturbance. Vegetation-based targets for ecosystem restoration will need to reflect this dynamic nature rather than the traditional view of a static, climax forest. The difficulty in identifying a "natural" vegetation for these areas has become increasingly apparent.

Tree-ring reconstruction of past giant sequoia fire regimes shows high temporal variability of fire frequency and size. Mean fire intervals from A.D. 500 to 1900 ranged from 3.0 to 4.1 years for different groves (range = 1 to 23 years; Swetnam and others 1992). No fire-free period in the last 2,000 years has been as long as that during the recent suppression era. In addition, historic periods of high fire frequency were apparently characterized by patchy fires (few trees show the same scar year), whereas periods of low-frequency fire were characterized by large fires (many trees show the same scar year). Climatic variation appears to account for much of the variability in past fire regimes (Swetnam 1993). One implication of the high temporal variability of the past fire record is that "natural" fire regimes cannot be characterized by a single fire frequency or mean fire interval estimate.

Despite concern over the effects of fire suppression, it is clear that sequoia ecosystems represent a dynamic forest type that is well adapted to environmental change. We now believe that no species have been lost or introduced to the sequoia forest as a result of fire suppression and that claims of increases in young white fir (Bonnicksen and Stone 1982) can only be confirmed once we have an improved understanding of normal population dynamics of mixed conifer forest species. The most significant finding in recent years has been documentation of the importance of patchy high-intensity fires in the perpetuation of giant sequoia (Stephenson and others 1991).

The scenic and emotional values associated with giant sequoia are immense (Cotton and McBride 1987; McBride 1993). In 1985, concern over the impacts of prescribed burning on scenic values (creating and enlarging fire scars and causing bark char) shut down the prescribed fire program for a year (Parsons 1990). Partly in response to such concern, extra efforts are now made to remove heavy fuel from around the base of giant sequoias before burning. In addition, in the most heavily used areas, Special Management Areas have been designated where burn boundaries and burning techniques are largely determined by scenic criteria.

# THE FUTURE

A 1993 review of the prescribed fire program at Sequoia and Kings Canyon National Parks recommended the following wording be used to state the goal of the prescribed fire management program: To restore and perpetuate the fire regime and the vegetation structure (or range of structural variability) that would have existed today had Europeans not come on the scene.

This wording formally recognizes the important ties between the fire process and the resulting vegetation. And although it is readily acknowledged that sufficient understanding of past vegetation and the interactions of fire, climate and vegetation do not exist to establish final vegetation-based objectives at this time, such a goal does provide a target to help direct future management actions and research studies.

To accomplish this goal it will be necessary to burn at an accelerated rate by expanding burning windows and increasing the use of larger, variable-intensity fires. Prescription changes will be needed to permit some fires that open the canopy. Reburning of areas burned in the recent past will need to be increased. It is unclear whether such changes can be effectively made in the face of a myriad of program constraints.

## Constraints

Among the significant constraints that threaten future progress of the giant sequoia prescribed fire program are funding and staffing limitations, air quality restrictions, public and concessioner use conflicts (including the effects of smoke), cultural and archeological concerns, requirements for expensive fuel manipulation around sequoias, and the lack of basic knowledge of long-term fire effects.

## Research Needs

The long-term success of the prescribed fire program is dependent on an improved understanding of past forest conditions, the effects of variable fire regimes and fire characteristics on ecosystem properties (including mortality, recruitment, pathogens, nutrient cycling, and so forth), the ecological and health effects of smoke, and smoke dispersion patterns. It will also be necessary to define the range of desired forest structure, develop models of forest and fuel dynamics and fire spread potential, and begin long-term studies of the effects of different burning patterns.

## Management Options

A number of significant challenges must be addressed if larger acreages are to be burned and the desired effects achieved. These include the need to increase the use of larger, variable-intensity ignitions that minimize the construction of firelines, and to expand burning windows to permit burning under a wider range of conditions. It will also be necessary to explore options for increasing the use of natural ignitions. Models of forest and fuel dynamics and fire spread will need to be increasingly relied on to project the consequences of alternative management

strategies. Feedback from monitoring and research findings will need to be improved both to refine objectives and techniques and to evaluate program success.

Finally, the time has come when the Parks must seriously consider alternatives to the use of fire for areas where it simply isn't possible to achieve natural fire frequencies. This may include the use of physical manipulation of fuels and vegetation. Long-term study areas may need to be established to demonstrate and learn the effects of alternative management strategies.

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# The Western Region Fire Monitoring Handbook

Paul Reeberg

National Park Service fire management guidelines (NPS-18) state that parks with prescribed fire programs must monitor those fires to ensure that fire behavior is assessed, and resource management objectives are met. The guidelines do not specify how the monitoring is to be done. The Western Region Fire Monitoring Handbook outlines standardized methods that are used within the Western Region of the National Park Service for documenting both wildfires and prescribed fires. It is intended to provide managers with the feedback necessary to either affirm that park objectives are being met or to identify and correct deficiencies.

The Handbook is designed to ensure that all parks collect at least the minimum information necessary to evaluate their respective fire management programs. There are many benefits to maintaining these minimums and standardizing data collection procedures. Uniformly gathered data facilitates information exchange between parks, and provides historical program documentation and data bases useful for refinements of the park's fire management program (fig. 1). Fire monitors can move to or assist other parks without additional training.

The monitoring protocol for prescribed burns is applied only in parks having approved prescribed fire management programs, and where fire effects on plant communities are already documented. This monitoring system does not provide a methodology to compare burned and unburned areas to assess fire effects with scientific precision. If such information is needed, parks will contact the Western Region Division of Natural Resources and Research, National Park Service, for assistance in designing the appropriate studies.

## FIRE MONITORING LEVELS

The Handbook is organized around fire management strategies that are outcomes of fire management goals. Each management strategy requires a minimum amount of monitoring, or Minimum Acceptable Standard level. Levels of monitoring activity are established and defined. At each successive level, monitoring is more extensive and complex. Level One covers reporting of all fires, and levels Two, Three, and Four call for monitoring of fire conditions, short-term effects, and long-term change, respectively.

Monitoring levels are applied cumulatively; at level Four, for example, all procedures of levels One through Three are carried out, as well as those specific to level Four. Monitoring at all four levels is required for prescribed burns.

All fires must be monitored at level One, Reconnaissance. Variables monitored include fire cause, location and size, fuels and vegetation type, fire behavior and weather, smoke conditions, and resource or safety constraints. The monitoring schedule is limited to the fire period itself. Data is recorded on the Individual Fire Report and sometimes on the Fire Situation Analysis.

Level Two, Fire Conditions, is required for prescribed natural fires and prescribed burns. It adds to the variables monitored an array of specifics descriptive of such conditions as topography and weather, fire characteristics, and smoke characteristics. Monitoring frequency depends on fuel type and phase of fire spread. Data is recorded on the Fire Situation Analysis and on forms included in the Handbook.

Level Three, Immediate Postfire Effects, and Level Four, Long-term Change, are required for all prescribed burns. Monitoring at level Three provides information on fuel reduction and vegetative change in a specific vegetation and fuel complex (monitoring type), and on other variables dependent on management objectives (see Table 1).

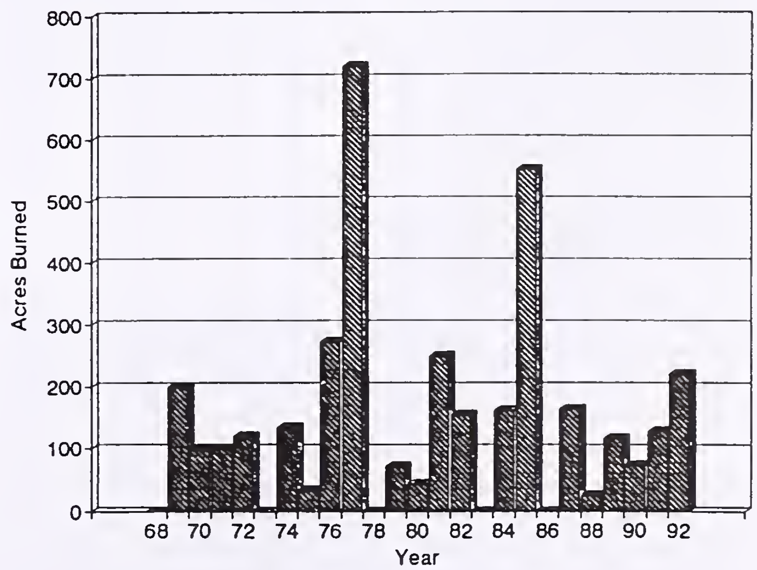


**Figure 1**—Total acreage of giant sequoia forest burned each year by management-ignited fires in Sequoia and Kings Canyon National Parks. In addition, 150 acres were burned in 1986 and 614 in 1991 in prescribed natural fires.

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**Table 1**—Monitoring vegetation type variables for level Three fire monitoring in the National Park Service's Western Region

| Vegetation type | Variables |
|---|---|
| Grassland (includes prairies and sedge meadows) | 1. Number of transect hits by species<br>2. Relative cover by species<br>3. Number of non-native species<br>4. Number of native species<br>5. Burn severity |
| Brush | 1., 2., 3., 4., and 5. as above<br>6. Brush density by species<br>7. Brush age by species |
| Forest or Woodland | 1., 2., 3., 4., 5., 6., and 7. as above<br>8. Tree density by species<br>9. Tree diameter by species<br>10. Fuel load by size class<br>11. Total fuel load<br>12. Duff depth<br>13. Litter depth<br>14. Average scorch height<br>15. Percent of crown scorched |

Vegetation and fuels monitoring is accomplished primarily through sampling of index plots in representative areas, and covers such items as percent non-native species, density, fuel load, and relative cover by species. Monitoring is carried out at varying frequencies before the burn, during the burn, and after the burn. Data is collected within one to five years after the burn.

Level Four monitoring, Long-term Change, is also required for prescribed burns, and may call for monitoring of the same variables as in level Three over a longer period. It is also concerned, however, with identification of significant trends over time that can serve as guides to management decisions. Some trends may not be statistically valid, but are nevertheless useful. Variables serving to reveal trends, or primary indicators, may be monitoring type, or objective-dependent, or may be non-standard. Monitoring frequency is based on an initial sequence of one, two, five, and 10 years after the burn; then plots are monitored every 10 years.

## MINIMUM ACCEPTABLE STANDARDS

The Handbook provides detailed instructions for defining a monitoring type, for establishing index plots, and for monitoring variables that are the Minimum Acceptable Standard. Index plots are designed to yield statistically valid results for detecting change in the environmental variables of interest. References describing methods for monitoring non-standard variables are provided. Variables dependent on prescribed burn objectives, as well as some primary indicators of long-term change, may require specific monitoring designs not covered in the Handbook. Aids such as random-number tables and data coding instructions are also provided. Data is recorded on forms included in the Handbook.

Minimum Acceptable Standards for fire monitoring, as established in the Handbook, will not answer all questions about the effects of fire management programs on ecosystems. Many Parks will still require research programs to study specific problems and to describe fire regimes. Parks are encouraged to expand long-term monitoring to include any additional physical or biotic ecosystem elements important to management, but not covered by the Minimum Acceptable Standards.

## MONITORING DESIGN

The Minimum Acceptable Standards variables are monitored by sampling according to a standardized design. Index plots form a representative area for each monitoring type, with or without control plots. Customized methods may be needed for special concerns; however, all customized methods and form modifications are approved by the Western Regional Office.

### Index Plots

Immediate postfire and long-term change monitoring is accomplished through the use of index plots—plots established before prescribed burning on which fire behavior and effects will be measured. Index plots are designed to yield statistically valid results for detecting change in the environmental variables of interest. Index plots will be randomly distributed throughout each monitoring type occurring within the burn units that are scheduled for burning within a five-year period. Additional plots are established in areas of special concern, such as a minor but very flammable fuel type occurring along a burn unit boundary.

### Representative Area

The collective aggregation of all index plots for a particular monitoring type constitutes a representative area. All index plots within a given representative area must be treated as a single data set for analysis purposes. Representative areas thus comprise a stratified random sample of monitoring types contained within areas proposed for prescribed burning within the five-year burning period.

A representative area data base is not used for quantitative assessments of immediate postfire effects or long-term change until all index plots comprising the area have been treated. Treatment consists of burning all the prescribed burn units in which the index plots are located. It could take up to five years to complete the immediate postfire effects data bases because of the burn schedule. Then the data bases will represent the immediate postfire effects and some of the long-term changes expected for all prescribed burns conducted under the same prescription and within the same monitoring type.

The "representative area" concept was specifically designed to negate the need to put plots in for every prescribed burn; this body of data should represent a large number of burns and thus lessen data collection overload.

## Data Entry and Analysis

Data is entered into IBM-compatible personal computers from standardized data sheets using the Fire Monitoring Handbook software—FMH.EXE. The data entry and analysis program uses dBASE data base software, but is a stand-alone package that can run without any software other than DOS.

The software program is available on a single 360K diskette. A software manual, called the Western Region Fire Monitoring Handbook Software Manual, is available as a companion document to the Western Region Fire Monitoring Handbook.

Data entry mimics standard data sheets. The addition of pull down menus, specific help, and extensive error checking makes the FMH.EXE program powerful and easy for computer novices to use. Any software that can access dBASE files (such as dBASE and FoxBASE) can be used to edit, enter, and analyze the data. Using FMH.EXE will enhance data integrity by providing validated data entry and will automate standard data analyses.

Once data is entered, analysis routines in FMH.EXE calculate all Minimum Acceptable Standards variables, and some recommended and optional variables. Minimum plots calculations also output the mean, standard deviation, standard error, and range.

The Western Regional Office maintains an annually updated data base consisting of all the data collected at participating Parks. There are currently 86 grassland plots (11% of total), 317 brush plots (40% of total), and 396 forest plots (50% of total) for a total of 799 plots in 74 monitoring types within the Western Region Fire Effects Monitoring Program.

## TRAINING

In support of the Handbook, three training courses have been developed by the Western Regional Office, National Park Service, and the Bureau of Indian Affairs. These courses are: RX-80 Preburn Inventory Techniques (seasonal orientation to plot installation), RX-91 Monitoring Prescribed and Prescribed Natural Fires (fire behavior monitoring), and RX-92 Fire Monitoring Program Design and Implementation (orientation to program management).

## PARTICIPATING PARKS

National Parks within the Western Region that are participating in this program are: Chiricahua National Monument, Golden Gate National Recreation Area, Grand Canyon National Park, Joshua Tree National Monument, Lake Mead National Recreation Area, Lassen Volcanic National Park, Lava Beds National Monument, Pinnacles National Monument, Point Reyes National Seashore, Redwood National Park, Saguaro National Monument, Santa Monica National Recreation Area, Sequoia and Kings Canyon National Parks, Whiskeytown National Recreation Area, and Yosemite National Park. Participating parks outside the Western Region include: Bandelier National Monument, Big Cypress National Preserve, Bryce Canyon National Park, Carlsbad Caverns National Park, North Cascades National Park, Voyageurs National Park, and Zion National Park.

Other government agencies and private organizations that are using or investigating the use of the Western Region Fire Monitoring Program include: California State Parks, Texas State Parks, Yuba Watershed Institute, Tall Timbers Research Station, Environment Canada Parks Service, USDI Fish and Wildlife Service, Bureau of Indian Affairs, Bureau of Land Management, and USDA Forest Service.

## PROGRAM MANAGEMENT

A standardized system to cover the wide diversity of areas within the Western Region is not without its problems. Each Park's monitoring program, therefore, is reviewed annually by the Fire Monitoring Handbook Program Manager, and refinements to the Handbook are made as necessary. Future refinements will lead to a National Fire Monitoring Handbook. Any Park unable to comply with the required standards will terminate their prescribed fire management programs until compliance can be assured.

The effectiveness of this fire monitoring program must be periodically reviewed at all levels (park, region, servicewide) and by various people (such as field technicians, park staff, regional staff, and outside scientists). The program will be evaluated periodically by a regional committee containing, at least, one superintendent, two resource management specialists, two fire management officers, two scientists, and the regional fire management program coordinator. An independent review of the program (by interagency scientists, resource managers, outside scientists, and fire ecologists) may also occur as determined by the National Park Service, Boise Interagency Fire Center or the Western Regional Office.

The purpose of the above program evaluations is to evaluate progress to date, and if necessary, to review and revise the goals and objectives of the program, the levels of accuracy and precision required, field methods and data processing procedures, and reports and publications. A written evaluation is distributed to all interested persons.

# Characterizing Severe Fire Behavior

Richard C. Rothermel

All forest fires are not alike; the nature of the differences provides an insight into expected fire behavior. The better the characteristics of fires can be recognized, anticipated, quantified, and illustrated, the better the chances we have of avoiding operational errors and tragedies. Fires carried through the crowns of coniferous forests can be one of the most extreme types of severe fire behavior. Compared to other types of fires, crown fires are relatively rare, but their impact is severe. Strauss and others (1989) found that in the Western United States, 1 percent of all fires accounted for 80 to 96 percent of the area burned.

## THE CROWN FIRE PHENOMENON

As the name implies, a crown fire is a fire carried through the crowns of living forests. Before reaching this condition, a fire can go through several stages of development. Typically, a fire may spread for some time in surface fuels such as grass, forest litter, or shrubs, without interacting with the overstory. It may even smolder in forest duff for days or weeks until burning conditions improve and the fire becomes active and begins to spread. Beighley and Bishop (1990) provide an excellent description of the transition from surface fire to crown fire in high-elevation forests. Favorable conditions for a crown fire include:

- Dry fuels
- Low humidity and high temperatures
- Heavy accumulations of dead and downed litter
- Conifer reproduction and other ladder fuels
- Steep slope
- Strong winds
- Unstable atmosphere
- Continuous forest of conifer trees.

Depending on the degree that some or all of the above conditions are encountered, the intensity of a fire in surface fuels will increase and flames will begin to reach into the crowns. Flames may also climb ladder fuels into the crowns where the needle foliage will ignite and one or more crowns will "torch." Torching is the sudden envelopment of an entire tree crown in flames in a few seconds. The flames may involve a single tree or a small group. If conditions for sustained spread through the crowns are not favorable, the torching trees will quickly burn out, but in the process showers of firebrands can be produced that are lofted and spread by the wind.

Most firebrands burn out before they fall. Many fall within the fire perimeter, but some are carried beyond the fire front where they settle on forest debris and start new fires. These are called spot fires, and the process is referred to as "spotting." Repeated torching produces small islands of burned out trees. Torching can occur at any time of the day, but increases in frequency as conditions become drier in the late afternoon. As this behavior continues, the stage is set for the development of a sustained crown fire. Again, depending on the degree that the conditions favoring a fire are present, a running crown fire will result, which can have a recognizable behavior pattern. The two most prominent behavior patterns are wind-driven fires and plume-dominated fires.

### Wind-Driven Fires

A running crown fire can result when the fire intensity increases sufficiently to carry the fire from crown to crown. Strong winds and steep slopes increase the probability of a sustained crown fire. As the name implies, a wind-driven fire is dominated by strong winds that drive the flames before it. Spread rates have been measured from 1 to 7 miles per hour, and may be faster up steep slopes. A running crown fire of any type is accompanied by showers of firebrands, fire whirls, smoke, and the rapid development of a strong convection column.

After running up the side of a mountain, a crown fire often stops at the top of a ridge where it may encounter discontinuous fuels or fuels with high moisture content. If there is little humidity recovery after sundown, fires will spread well into the night as the Yellowstone fires did in 1988 (Hartford and Rothermel 1991). During drought conditions, fuels are ready to burn regardless of topography. When the wind is strong and sustained, a running crown fire may continue and spread for several hours, burning out entire drainages and crossing mountain ridges that would normally be barriers. A dramatic example of a wind-driven crown fire took place on September 6, 1988, when the Canyon Creek Fire crossed the Continental Divide and burned onto the plains in west-central Montana (Goens 1990).

### Plume-Dominated Fires

There can be an alternate form of crown fire with a significantly different behavior pattern from the wind-driven crown fire described above. These plume-dominated fires are associated with relatively low windspeeds, usually less than 20 mi/h at the 20-ft level, and the development of a strong convection column, or plume, that towers above the fire rather than leaning over before the wind. To indicate the importance of the convective plume and to differentiate it from wind-driven fires, such fires will be called plume-dominated fires.

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Plume-dominated fires can cause unexpected and serious problems in at least two different ways. The first, which Byram (1954) described as a blowup fire, results when the size and intensity of the fire produce extreme turbulence at the base of the convection column. The pulsing flow and turbulence increases fire intensity and heat transfer to adjacent fuel, accelerating fire spread. The process feeds on itself and accelerates as the convection column grows. This condition is described in Byram's (1954) paper. In recent years, two plume-dominated fires of this type have been documented: the Butte Fire in 1985 in which 73 firefighters were forced into their fire shelters (Mutch and Rothermel 1986; Rothermel and Gorski 1987; Rothermel and Mutch 1986), and the Mack Lake Fire, in which one firefighter was killed (Simard and others 1983). When the Mack Lake Fire blew up, it spread through a jackpine stand at 7 mi/h with gradient winds of only 20 to 25 mi/h. This rapid spread is comparable to the maximum observed on the Sundance Fire, which spread at about 6½ mi/h while being driven by a 40 mi/h wind (Anderson 1968).

The second way in which a plume-dominated fire can be extremely dangerous occurs when a downburst of cold air descends from the convection column and blows outward along the surface at high speeds in all directions. These winds can be extremely strong (Haines 1988b) and very dangerous because they occur so suddenly. If the winds reach the fire, which is very likely, the fire becomes wind-driven for a short but very violent period in which extreme spread rates may occur.

Downburst is initiated as precipitation evaporates, cooling surrounding air. Because cool air is denser, this localized cell of air descends rapidly, producing a downburst or microburst as described by Haines. The author encountered such a phenomenon near the Shoshone Fire in Yellowstone National Park on July 23, 1988. In this case the fire was not being driven by the downburst winds, but these winds were strong enough to uproot and break off trees. The broken trees could be seen for 3½ miles along the Park's south entrance highway. The downburst must have come from the fire's convection column, since there were no other cumulus clouds in the area. Very light rain was felt approximately one-half hour before the downburst. This, too, must have come from the fire's convection column; it may have continued as virga (rain evaporating before reaching the ground), but this was not observed.

Personnel on a fireline should watch for conditions that may indicate the development of a downburst from a plume-dominated fire. The surest indicator is the occurrence of precipitation of any amount, even a light sprinkle, or the appearance of virga. Precipitation cannot always be counted on to reach the surface, especially in the dry western climates. Other indicators are the rapid development of a strong convection column directly over the fire, or the presence of nearby thunder cells. All crown fires have a convection column in some form, and a person beneath a column cannot see its vertical development; but observers around the fire periphery could call attention to any large column growing vertically above the fire front. A third warning of a downburst is the calm that develops when the indraft stops just before the turnabout and outflow of wind from the cell. During this period on the Shoshone Fire we heard a strange humming sound that grew louder just before the wind hit.

Topographic features can aggravate the situation. Downburst winds can be prolonged and strengthened when they are channeled through canyons. Locations downhill from a fire cannot be considered safe because the downburst winds can drive the fire very rapidly downhill.

New information is helping to predict severe fires. The Haines Lower Atmosphere Severity Index (Haines 1988a) is a simple and easily applied index that considers the instability and moisture levels of the lower atmosphere. The index, also known as the Haines Index, rates these features of the atmosphere for their potential to promote large fire growth. Fire weather meteorologists Paul Werth and Richard Ochoa (1990) have examined Haines' index on several fires in Idaho with excellent results.

Fires are seldom uniform and well behaved; these descriptions of wind-driven and plume-dominated fire behavior may not be readily apparent on a given fire. The behavior of any fire can be expected to change rapidly as environmental, fuel, and topographic features change. During the course of a running crown fire, several of these behavior patterns may be displayed.

A fire characteristics chart (fig. 1) developed by Rothermel (1991a,b) can display several important features of a severe

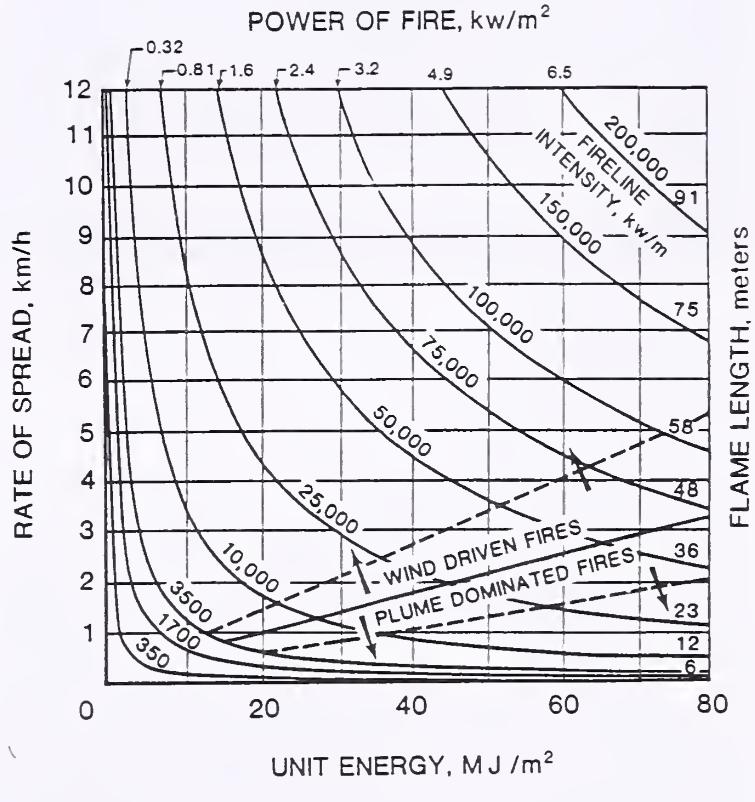


**Figure 1**—A crown fire characteristics chart showing the five fire behavior elements: Unit energy or heat per unit area produced by the available fuel, Rate of spread at the fire front, Fireline intensity at the fire front, Flame length, and the Power of the fire. The solid line crossing the chart is the equivalent power line where the power of the fire is predicted to equal the power of the wind on level terrain.

fire. Any point on the chart provides a simultaneous indication of rate of fire spread, heat energy provided by the fuel per unit area, fireline intensity, flame length, power of the fire, the probable type of crown fire, and the difficulty of fire control. The contrast in behavior between different fires can readily be seen when they are plotted on the same chart. Another feature, based on the power of the fire relative to the power of the wind, indicates whether the fire will be wind-driven or dominated by the convection column. Comparisons with actual fire observations indicate that these features are correctly indicating fire characteristics.

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# Using a Geographic Information System for Presuppression Planning of Lightning-Ignited Wildland Fires in Missoula County, Montana

**Jon Skinner**
**Ronald H. Wakimoto**

Locating lightning-ignited wildland fires following the passage of a storm is an expensive procedure that often strains the funding and manpower available to fire suppression forces.

In Missoula County, MT, during the years 1985 to 1990 approximately 17,000 cloud-to-ground lightning strikes accounted for slightly more than 33 percent of the wildland forest (more than 600 lightning-ignited wildland fires). Although the number of strikes and ignitions cannot be reduced or eliminated, knowing where forest are likely to occur would help the land manager use resources effectively.

This study will demonstrate the use of a Geographic Information System for presuppression planning of lightning-ignited wildland fires in Missoula County. A map and associated databases will be constructed. Spatial, temporal and statistical analysis will determine a functional relationship among various characteristics for Missoula County and the map-predicted fire areas. The characteristics to be studied include cloud-to-ground lightning strikes, lightning-ignited wildland fires, National Fire Danger Rating System indices, fuel models, aspect, and elevation classes. This will be accomplished by acquiring Automated Lightning Detection System strike information, lightning-ignited wildland fire data, National Fire Danger Rating System data, and other fire-related information from various federal, state, and local fire organizations.

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# The Galusha Peak Fire: a Case Study in Wilderness Management

**Charles W. Spoon**

In 1988 the Canyon Creek Fire burned in the Scapegoat Wilderness, part of the Bob Marshall Wilderness Complex. This fire was started by a lightning strike on June 24. It was put into a Prescribed Natural Fire status and burned from June to September, covering over 240,000 acres. Inside the Scapegoat Wilderness boundary, 58,000 acres burned. The burn left many unburned islands inside the fire's perimeter.

On August 9, 1991, a lightning-caused fire was reported just off Galusha Peak inside one of the unburned islands in the Canyon Creek Fire. This fire, following the appropriate analysis, was suppressed. Although it was suppressed because of an unsigned Fire Management Action Plan, considerable discussion ensued around a previously undiscussed wilderness issue. Briefly stated: "In our desire to return fire to its natural role in wilderness, can there be a condition when we have too much area in a recently burned condition?"

Given the wilderness resource, would it be appropriate to limit the area burned by suppressing all new fire starts or should we truly allow fire to play its natural role, as nearly as possible? The question raises some very important issues:

- Who determines how much fire is right for a wilderness? Humans or nature?
- If humans decide, is this consistent with the mandate in the 1964 Wilderness Act?
- Should special protection be given to old growth, threatened and endangered species, recreation use, commercial use, and other concerns?
- Is any type of "special protection" consistent with the 1964 Wilderness Act?

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The Lolo National Forest decided to suppress the Galusha Peak Fire because of an unsigned Fire Management Action Plan. However, as a result of this Fire, the Forest had to determine how to deal with new natural starts in these few unburned islands within the Canyon Creek burn. The Forest Supervisor made the decision to allow fire to play its natural role within the criteria presented in the Fire Management Plan.

The Forest leadership personnel looked into many of the issues surrounding this issue. They understood the possibility of new starts burning additional acres of the remaining unburned islands, but believed that was nature's decision. The concerns over burning the remaining elk security cover and remaining old-growth patches, impacting visitors' desire for vegetative variety, and impacting commercial use were considered secondary to the very essence of wilderness. The leaders believe very strongly that wilderness managers should not override the Fire Management Plan because of human concern over how much fire is enough in wilderness. We believe nature should determine the extent, periodicity, season, and intensity of fire within the framework of the Fire Management Plan. We believe this naturalness is what makes wilderness different from nonwilderness lands.

This issue may be faced by other wilderness managers or line officers having control over wilderness management. Today we are struggling over the need to reintroduce fire into fire-dependent wilderness communities. We feel strongly that due to the over half-century of fire exclusion, we need to quickly return fire to our western wilderness areas. However, if one believes we will eventually be successful in this attempt, there may be the time when over a short time period, more land will be in a recently burned condition than in an unburned condition. When this happens, managers and line officers will have to make some difficult decisions. At risk will be the future of wilderness as intended by the 1964 Wilderness Act. We feel these managers and line officers must make the decision as close to the Act's intent as is socially and politically acceptable.

# Fire and Clark's Nutcracker Aid Whitebark Pine Regeneration

**Diana F. Tomback**
**Stephen F. Arno**

Whitebark pine (*Pinus albicaulis*) is a high-elevation conifer of western North America, whose cone crops are an important food source for wildlife (Arno and Hoff 1989; Schmidt and McDonald 1990). This tree depends on the Clark's nutcracker (*Nucifraga columbiana*) to disperse and bury its heavy, wingless seeds in the soil. The nutcracker retrieves many of its caches for food, but many unretrieved seeds germinate and become new whitebark pine trees. On most sites in the Northern Rocky Mountains, whitebark pine's perpetuation also depends on fire. Without fire the pine is eventually replaced by shade-tolerant subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*). Nutcrackers readily cache whitebark pine seeds in recent burns, often transporting them over long distances. Because of nutcracker seed dispersal, whitebark pine has a regenerative advantage over competing conifers—whose seeds are dispersed by wind, generally over short distances. Within 100 years after fire, whitebark pines often become vigorous cone-bearing trees. After another century or two without fire, the trees lose vigor and are replaced by competing fir and spruce. However, when an old stand burns, the nutcracker is likely to transport whitebark pine seed onto the burned site, restarting the successional cycle.

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# Effects of Livestock Grazing on Pre-Settlement Fire Regimes in New Mexico

**Ramzi Touchan**
**Thomas W. Swetnam**
**Henri D. Grissino-Mayer**

In this study we investigate the effects of livestock grazing on fire regimes in northern New Mexico. We accomplish this by reconstructing and comparing multi-century fire histories of ponderosa pine forests in areas with different grazing histories. Contrasting fire histories in these areas reveal the importance of land use history in the interpretation of pre-settlement fire regimes. The current structure and functioning of these ecosystems are intimately linked to past fire regimes. Consequently, knowledge of grazing practices and their potential effects on past fire regimes is important for interpreting, understanding and managing modern forests.

## DESCRIPTION OF STUDY

### Study Areas

Fire-scarred trees were sampled in north-central New Mexico in the Monument Canyon Natural Area. Grazing did not begin in this central area of the Jemez Mountains until the late 1800's (Allen 1989). Elevation is about 2,600 meters, with variable aspects. Large ponderosa pine dominate in the overstory. Scattered dense clumps of small diameter pines (dog-hair thickets) occur throughout the stand. These dense stands are an indirect result of fire suppression, since continuation of frequent low-intensity surface fires would have thinned the stand.

Fire-scarred trees were also sampled in north-central New Mexico at a site we call Continental Divide located on the western slope of the Jemez Mountains. This area has a long history of livestock grazing by Navajo and Hispanic populations, beginning in the early 1700's (Bailey 1980). The sampled area encompasses three adjacent sites: Laguna Gurule; Laguna Jaquez; and Continental Divide. The average elevation is 2,300 meters with south- to southwest-facing aspects. The area is characterized by low ridges covered by ponderosa pine (*Pinus ponderosa*), and scattered Rocky Mountain juniper (*Juniperus scopulorum*). The drainages are broad and shallow with sagebrush (*Artemisia tridentada*) and grasses interposed among the ridges.

A third area was sampled in west-central New Mexico in El Malpais National Monument. This area encompasses two isolated sites, Mesita Blanca and Hidden Kipuka. These sites are "kipukas," or islands of older substrate completely surrounded by more recent lava flows. The kipukas are inaccessible to domestic livestock because of the very rugged and broken terrain of the lava, and therefore have not been intensively grazed (Grissino-Mayer 1993). The average elevation is 2,100 meters. This area supports two vegetation types—an open ponderosa pine forest and a pinyon-juniper forest. Trees are widely spaced in these stands with grasses as ground cover.

### Methods

We collected fire-scarred samples from 30 trees distributed over 259 hectares in the Monument Canyon Natural Area site, 27 trees distrubuted over 27 hectares in the Continental Divide site, and 39 trees distributed over 56 hectares in the El Malpais National Monument site. Full or partial cross-sections were cut with a chainsaw from fire-scarred boles of downed logs, snags, and stumps. In the laboratory, samples were fine-sanded and crossdated using dendrochronological techniques (Stokes and Smiley 1968).

All fire-scar dates from individual trees within each site were compiled into master fire chronology charts so that both temporal and spatial patterns of past fire occurrence could be examined. Descriptive statistics were also computed, including fire frequency (number of fires per time period), percentage of trees scarred, mean fire interval, maximum and minimum fire interval, and standard deviations of fire intervals. These statistics were computed for all fire dates and for fire dates recorded by more than 10% of the fire-scarred trees. The latter computations generally emphasize the larger, more widespread fires within the sites.

Changes in fire frequency through time were examined by computing and plotting moving-period fire frequencies. The moving periods were overlapping time periods of different length (51 and 21 years) during which the total number of recorded fires were summed. Each sequential value was the summation of fire events in the time period lagged one year forward from the previous period. The fire frequencies in these moving periods were plotted on the central-year of the period.

The computation of mean fire interval, maximum and minimum fire interval, and standard deviations were based on a time period when the number of fire-scar samples was deemed sufficient to reliably estimate fire regime characteristics. Generally this was at least four samples recording the fire events.

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Ramzi Touchan is Research Specialist, Thomas W. Swetnam is Associate Professor of Dendrochronology, and Henri D. Grissino-Mayer is Graduate Research Associate, Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ 85721.

## RESULTS

The fire-scar samples contained abundant and well-preserved records of past fire. We crossdated specimens from trees and downed logs that established more than 400 years before the present. Individual fire-scarred samples typically contained five or more fire scar dates. Collectively the samples from the Monument Canyon Natural Area extended from A.D. 1408 to 1972, with 57 fire scar dates between 1493 and 1909. Samples from the Continental Divide site spanned a 592-year period between 1387 and 1979, with 54 fire scar dates between 1601 and 1899. Samples from the El Malpais National Monument extended from A.D. 1407 to 1991 with 66 fire scar dates between 1447 and 1989.

The mean fire intervals for fires recorded by more than 10% of trees were not greatly different among the three sites when only the periods of reliability were considered (see Table 1). However, the data in Table 2, for the time period of 1750 to 1899 show a different result. The mean fire interval for the Continental Divide site, where more than 10% of trees are scarred, is much larger than for the other two sites. The maximum and minimum fire intervals are also larger.

## DISCUSSION

A sharp decline in fire frequency after about 1880 was observed in virtually all southwestern fire history studies (Weaver 1951; Dieterich 1980; Allen 1989; Swetnam 1990). The fire frequency decline coincided with the beginning of intensive livestock grazing (especially by sheep) in each study area and preceded organized fire suppression by one to three decades. This pattern is exemplified by the Monument Canyon Natural Area fire chronology where we observed an abrupt cessation of fires around 1899 (Figures 1, 2, and 3). The last major fire occurred in 1887. Allen (1989) and Rothman (1992) reported that the number of livestock in the Jemez Mountains was very high by 1880 because of the development of local railroad links to external markets. The Roman Vigil Grant on the Pajarito Plateau in the Jemez Mountains was leased to a Texas stockman who grazed 3,000 cattle on 13,000 hectares from 1885 to 1887, about ten times the modern carrying capacity (Foxx and Tierney 1984; Allen 1989). Wooton (1908) reported that the number of sheep in 1880 in New Mexico was 2,088,831; by 1906 the number had increased to 4,558,365. The magnitude and impact of this intense grazing is vividly illustrated by a quote from Rixon (1905), an early surveyor

**Table 1**—Summary of fire interval statistics for two sites in Northern New Mexico. Mean fire intervals (MFI), standard deviations (STD), and maximum and minimum fire intervals (Max. and Min. F.I.) for all fires and for fires that scarred at least 10% of trees for the period of reliability (1648 to 1892 for the Monument Canyon Natural Area, 1654 to 1880 for the Continental Divide site, 1625 to 1976 for the El Malpais National Monument. All values are expressed in years

| Site Name | Site Code | MFI All Fires | MFI ≥10% Trees Scarred | STD All Trees | STD ≥10% Trees Scarred | Max. F.I. All Fires | Max. F.I. ≥10% Trees Scarred | Min. F.I. All Fires | Min. F.I. ≥10% Trees Scarred |
|---|---|---|---|---|---|---|---|---|---|
| Monument Canyon Natural Area (Late Grazed Area) | MCN | 5.5 | 6.6 | 2.6 | 2.9 | 12 | 16 | 1 | 2 |
| Continental Divide (Early Grazed Area) | CON | 6.5 | 9.8 | 6.8 | 12.7 | 28 | 48 | 1 | 2 |
| El Malpais (Ungrazed Area) | ELMA | 6.6 | 10.6 | 4.8 | 8.2 | 22 | 41 | 1 | 1 |

**Table 2**—Summary of fire interval statistics for three sites in Northern New Mexico. Mean fire intervals (MFI), standard deviations (STD), and maximum and minimum fire intervals (Max. and Min. F.I.) for all fires and for fires that scarred at least 10% of trees from 1750-1899. All values are expressed in years

| Site Name | Site Code | MFI All Fires | MFI ≥10% Trees Scarred | STD All Trees | STD ≥10% Trees Scarred | Max. F.I. All Fires | Max. F.I. ≥10% Trees Scarred | Min. F.I. All Fires | Min. F.I. ≥10% Trees Scarred |
|---|---|---|---|---|---|---|---|---|---|
| Monument Canyon Natural Area (Late Grazed Area) | MCN | 5.7 | 6.7 | 2.8 | 2.8 | 12 | 12 | 1 | 2 |
| Continental Divide (Early Grazed Area) | CON | 12.0 | 30.0 | 10.4 | 19.8 | 28 | 48 | 1 | 10 |
| El Malpais (Ungrazed Area) | ELMA | 7.5 | 11.6 | 5.1 | 8.0 | 22 | 24 | 2 | 2 |

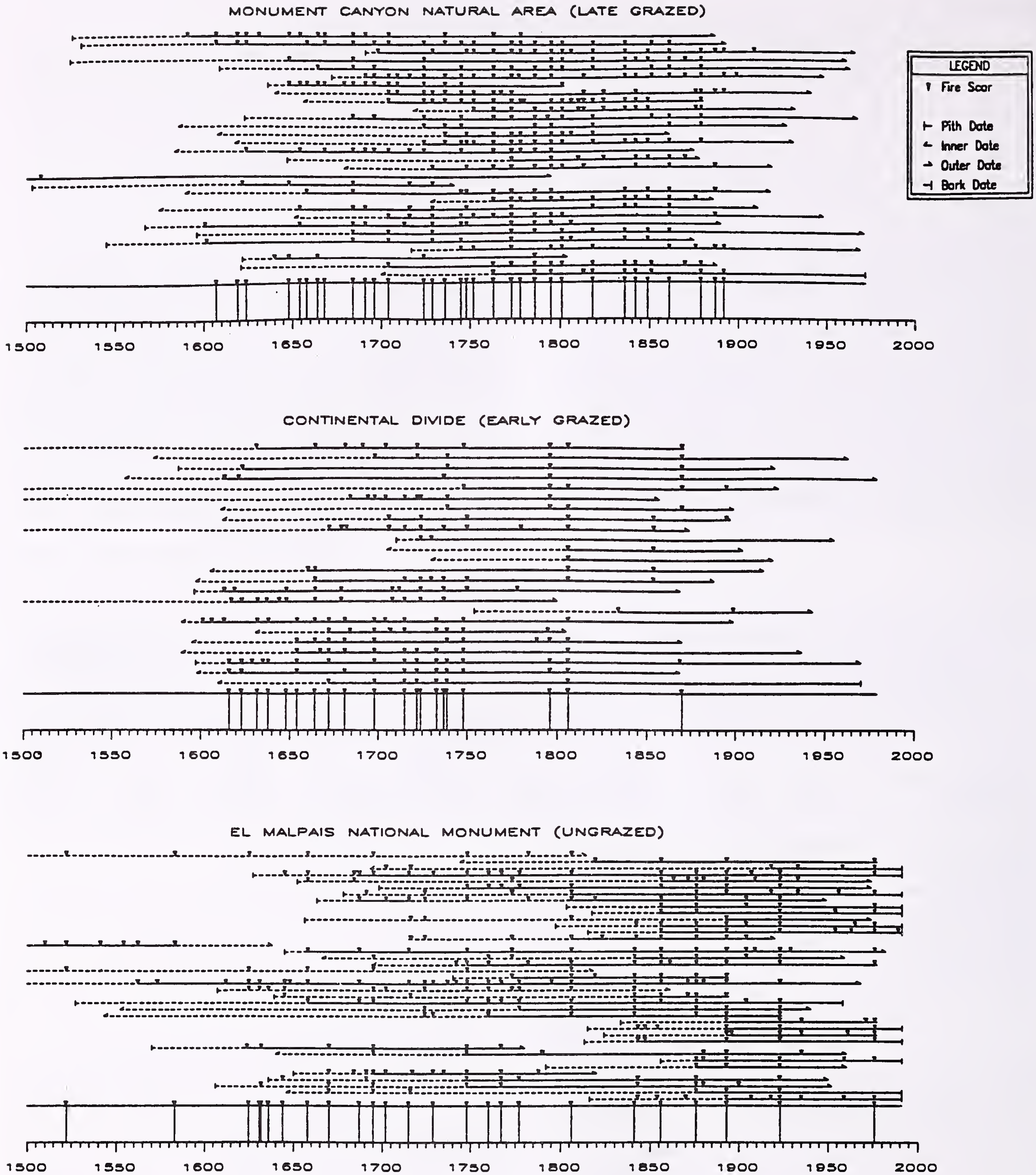


**Figure 1**—Master fire chronologies for three sites in northern New Mexico. Horizontal lines are life spans of sampled individual trees and arrowheads are fire-scar dates. Fire dates recorded by 25% of the sampled trees are shown on the lowermost line, with vertical lines extending to the time scale.

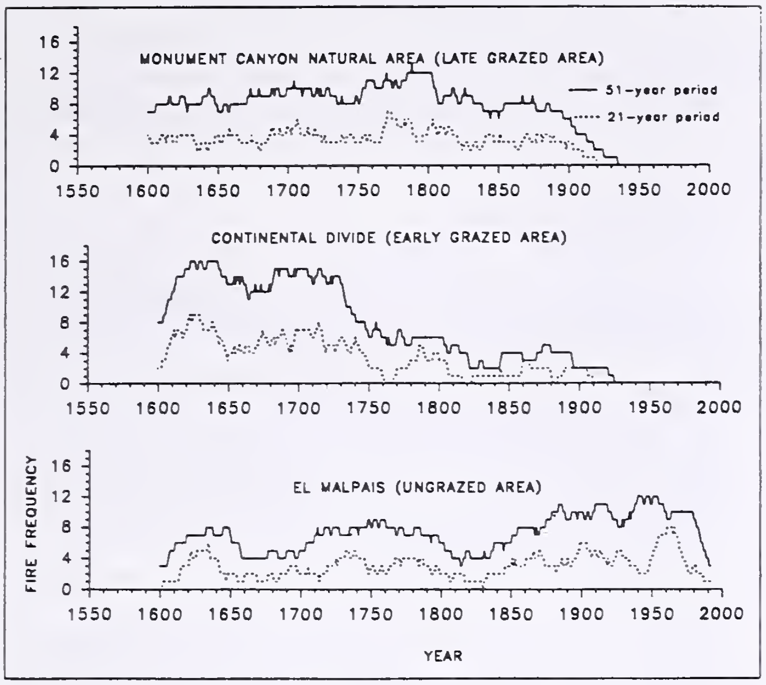


**Figure 2**—Fire frequency (number of fires per period, based on all fire dates) for the three study sites in northern New Mexico. Moving periods of 51 and 21 years were used for computing the fire frequencies. The frequencies are plotted on the central year of the moving period.

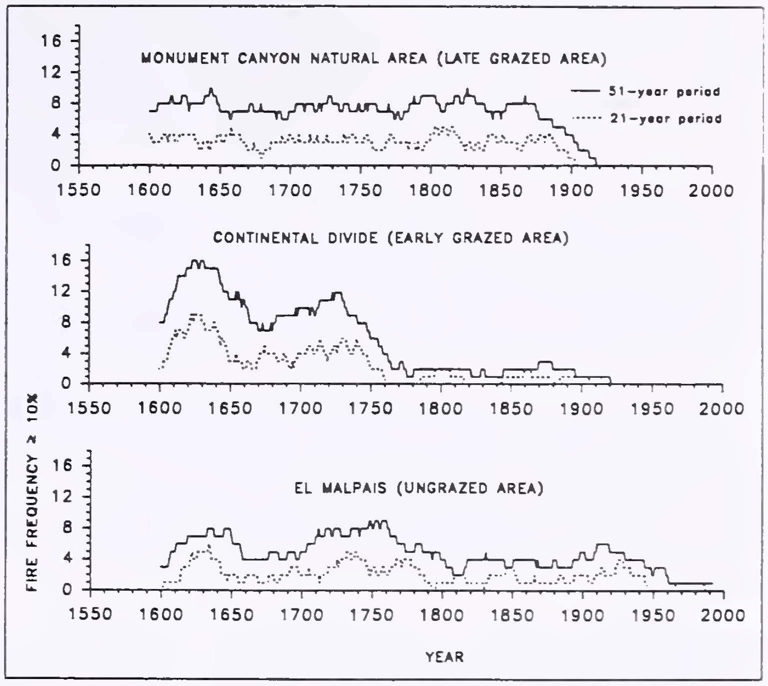


**Figure 3**—Fire frequency (number of fires per period, based on dates of fires that scarred at least 10% for sampled trees for the three study sites in northern New Mexico. Moving periods of 51 and 21 years were used for computing the fire frequencies. The frequencies are plotted on the central year of the moving period.

(around 1904) of the Gila River Forest Reserve of southwestern New Mexico, in an area that is now ponderosa pine savanna:

> A large area which was entirely given up to sheep, has been overstocked, with the result that about half the township is a barren desert, not a blade of grass being seen and even the roots being entirely destroyed. When the wind blows, the sand and soil rise in vast clouds. I have been informed that this district, previous to the advent of sheep, was a fine grazing area covered with the most succulent grasses.

Hence, it is likely that wherever such intensive grazing occurred, the previous high-frequency fire regimes, depending at least partly on grass fuels, would have been affected.

A similar abrupt and persistent decline in fire frequency also occurred at the Continental Divide site, but much earlier than at Monument Canyon. The Continental Divide master fire chronology shows a sudden decrease in the fire frequency between 1750 and 1796. Scattered fires occurred around the turn of the 19th century, then another gap is evident between 1806 and 1854 or 1870, depending on the portion of the site represented (Figures 1, 2, and 3). These gaps could be due to early grazing by sheep as this area was subjected to early use by both Navajo and Hispanic herdsmen (Bailey 1980).

There is clear evidence that livestock were present in this area during the 16th and 17th century. The Spanish introduced livestock in northern New Mexico in 1598 (Baydo 1970; Bailey 1980). Baydo (1970) reported that during the late 16th and 17th centuries the Indians of the northern Mexico frontier traded livestock into the Southwest, and by 1680 all of the tribes of the border area had livestock in relative abundance. Bailey (1980) estimated the number of sheep that Navajo owned in northern New Mexico to be 8,000 by 1721, 32,000 by 1735, and 64,000 by 1742. The total probably reached a half-million by the mid-19th century (Bailey 1980).

A fire history study in ponderosa pine forests of the Chuska Mountains on the Najavo Indian Reservation (west of the Jemez Mountains) showed an early fire decline beginning around the mid-1800's that may have corresponded with the rise of intensive sheep herding by the Navajo in this area (Savage and Swetnam 1991). Savage (1991) reported that at least 500,000 sheep grazed the Navajo Reservation in the Chuska Mountains during most of the 19th and 20th centuries.

Fire frequency in the relatively ungrazed El Malpais National Monument remained approximately the same in the 19th and 20th centuries (Figures 1, 2, and 3). The more-or-less continuous fire regime into the 20th century is a very rare phenomenon in the southwestern U.S., where more than 30 other fire history studies show a sharp decline in fire frequency after about 1880 (Swetnam 1990, unpublished data). We have observed such an uninterrupted fire regime in only one other remote southwestern mountain range located in northern Sonora, Mexico (Baisan and others, this proceedings). We believe the continuation of frequent surface fire regimes during the 20th century in these areas is due to a combination of lack of intensive grazing and lack of fire suppression by firefighting agencies.

In summary, we observed a decline in fire frequency starting at the end of the 19th century in the Monument Canyon Natural Area. At another site (Continental Divide) which had a long history of sheep grazing by Navajo and Hispanic herdsmen, we observed an early decrease in fire occurrence in the late 18th and early 19th centuries. In contrast, the El Malpais National Monument, which was isolated from grazing impacts, shows a relatively uninterrupted history of spreading surface fires.

Based on these observations and other related work (Savage and Swetnam 1991), we conclude that intensive sheep grazing was the initial and primary reason for the decline in frequent large surface fires in many southwestern forests. The intensive grazing reduced fine fuel (such as grasses) necessary to carry fire from one tree to the other. Also, trampling of fuels, and trails made by livestock and herdsmen, probably limited fire spread in these forests. Frequent large fires were effectively eliminated by subsequent fire suppression by land management agencies.

## CONCLUSIONS

Intensive sheep grazing reduced fine fuels necessary for fire spread in the high-frequency fire regimes of the southwestern United States. Intensive livestock grazing, followed by reduced grazing, favorable climate, and fire suppression resulted in increased forest density in the 20th century. Reduced competition from grass for moisture and light and subsequent favorable germination and establishment conditions enabled many thousands of tree seedlings to develcp into dense dog-hair thickets (Madany and West 1983; Weaver 1951). Declines in fire frequency may also have favored tree regeneration during the long fire-free intervals of the 18th and 19th centuries at the Continental Divide. This would be especially likely if intensive sheep grazing by Navajo and Hispanic Peoples was intermittent, allowing pine seedlings to establish.

If this is the case, then it is likely that the structure (age distributions and species composition) of ponderosa pine forests that sustained early livestock grazing and early declines in fire occurrence differ from forests that did not sustain altered fire regimes until the late 19th century (most of the Southwest forests), or the very rare forest islands that did not sustain intensive grazing and the consequent decline in fire occurrence (the kipukas at El Malpais). Study of contrasting fire regimes, and the canopy and understory structures of such areas, may provide new insights into ecosystem trajectories of natural and human-disturbed forests. Better understanding of these dynamics is needed for predicting the outcome of 20th-century grazing and fire-suppression related changes in ponderosa pine forests. This understanding may provide some guidance for restoring structures and processes that will impart greater stability and health to southwestern forests.

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# The Natural Role of Fire in the Marble Mountain Wilderness

**Dale A. Thornburgh**

In 1987 lightning strikes started a series of fires that burned 45,067 acres in the western portion of the Marble Mountain Wilderness of northern California. These fires burned with varying intensities in the three main elevational forest vegetation types; low-elevation Douglas-fir/ hardwood forests, mid-elevation white fir forests, and high-elevation mountain hemlock/true fir forests. The fire burned 29,163 acres with low intensity, 7,309 acres with medium intensity, and 8,595 acres with high intensity.

## METHODS

During the summers of 1991 and 1992, forest stand species and structural fire-caused changes were recorded on 20- x 60-foot contiguous plots, located along four 1-mile-long strips in the McCash Lake, Secret Lake, Morehouse Meadow, and Steinacher Creek areas of the Marble Mountains. The information mapped and recorded for each plot included a spatial inventory of all trees, snags, and down logs. Species, diameter, height, crown length, snag and log condition, and fire damages before and after 1987 were recorded for each stand structural component. This information provides a means to assess the interaction of the mosaic of fires of varying intensity across the landscape of highly diverse forest stands.

## HISTORIC FIRE OCCURRENCE

At several locations in the forests dominated by white fir the last disturbance fire was approximately 68 years before the 1987 fire. Before that fire, the mean interval of disturbance fires was approximately 29 years. To the north of the Marble Mountains in the Siskiyou Mountains the last disturbance fire was 64 years ago with a mean fire interval of 25 years (Atzet and Martin 1991).

## NATURAL ROLE OF FIRE IN THE WHITE FIR FORESTS

Some of the white fir forests in the Marble Mountains are dominated by white fir (*Abies concolor*) and enriched with a mixture of other conifers that irregularly occur across the landscape as individuals or in small groups. Some of the other conifers include: *Abies amabilis, A. lasiocarpa, A. procera, A. magnifica, Calocedrus decurrens, Chamaecyparis lawsoniana, C. nootkatensis, Picea breweriana, P. engelmannii, Pinus albicaulis, P. attenuata, P. balfouriana, P. contorta, P. jeffreyi, P. lambertiana, P. monticola, P. ponderosa, P. sabiniana, Pseudotsuga menziesii, Taxus brevifolia, Thuja plicata, Tsuga heterophylla,* and *T. mertensiana.*

These white fir/conifer-enriched stands had an average of 32 canopy gaps per hectare before the fire. These prefire gaps averaged 37 square meters, ranging in size from 7 to 352 square meters. Most of the coniferous tree regeneration of all species occurred in these canopy gaps. The 1987 fire burned through these prefire gaps as a low- or medium-intensity fire. All small trees were killed by the fire in 63% of the gaps; a portion of the small trees were killed in 21% of the gaps; none of the small trees were killed in 16% of the gaps.

In these stands the 1987 fires created new gaps. Eighty-seven percent of the trees larger than 25 cm in diameter killed by the fires were burned in small groups of two to five trees, creating 26 new canopy gaps per hectare. After 5 years most of the coniferous species were regenerating from seed in both the new and old gaps.

The relatively frequent low- to medium-intensity fires maintain the gap and clumpy stand structure of this forest type, creating varied gap conditions that allow the diverse mixture of different coniferous tree species to reproduce in the different-sized gaps. The enriched mixture of coniferous species in these white fir forests is a direct result of the past fire patterns.

The high-intensity fires in the forests dominated by white fir occurred in areas that were dominated by young stands of pure white fir, open stands of white fir with a shrub understory, and montane chaparral. The fires burned through these shrub and fir stands at high intensity, usually killing all trees and shrubs. Five years after the fire, these stands were a solid mixture of young shrubby *Quercus, Ceanothus, Arctostaphylos, Prunus,* and *Holodiscus* that regenerated from buried seed or root crown sprouts. White fir slowly regenerates and eventually dominates as a single species stand. Repeated fires tend to maintain these white fir forests with shrub understories. They have low biodiversity.

In the forest stands of white fir with old-growth characteristics, most of the fires were of low intensity, and

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burned most of the down rotten logs and standing snags with very little damage to the canopy trees.

## ROLE OF FIRE IN THE LOW ELEVATION DOUGLAS-FIR/ HARDWOOD FORESTS

Low-intensity fires in the old-growth Douglas-fir/hardwood forests tended to burn all of the down rotten logs and standing snags. All of the 87 prefire down logs intersected by a 1-mile-long line intersect plot were totally consumed by the fire. Most of the understory small seedlings and saplings were killed by the fire. These fires tended to reduce the old-growth characteristics of the stands, potentially reducing the biodiversity.

Medium-intensity fires damaged or killed individual canopy trees or groups of canopy trees, creating new canopy gaps that provided opportunities for regeneration of future canopy recruits, maintaining the highly diverse old-growth canopy structure.

The 1987 fire created 12 gaps per hectare in the Douglas-fir/hardwood forest. These gaps had an average size of 157 square meters, ranging from 46 to 381 square meters.

## EFFECTS OF THE FIRES ON HUMAN WILDERNESS VALUES

The fires burned to edges of meadows, lakes, and trails leaving numerous meadows and lakes rimmed with blackened, dead trees. The fires eased cross-country travel by burning the shrubs, small trees, and down logs. Lakes without access trails were easily accessible up to 5 years after the fires.

## CONCLUSIONS

The high diversity of coniferous tree species found in the Marble Mountains, the diverse stand structure, and intermixing of different seral stages in old-growth canopy gaps result from the mosaic of low-, medium-, and high-intensity fires at fairly frequent fire intervals.

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# Wildland Fire Management and the Fire Regime in the Southern Canadian Rockies

J. M. H. Weir
K. J. Chapman
E. A. Johnson

Prescribed fires (fire burning under specified fire behavior) have often been proposed as a means of re-introducing fires into wilderness or natural areas where natural wildfires are no longer tolerated (Fisher 1984). Planned or unplanned prescribed fires are commonly carried out when prescribed fire is required over the entire landscape. Planned, landscape prescribed fires are ignited in landscape units under specific prescriptions and with a predetermined frequency. Unplanned, landscape prescribed fires are allowed to burn under certain "prescribed" fire behavior conditions, but ignition is unplanned ("wildfires"). However, when unplanned fires occur outside the prescribed fire behavior conditions, they are suppressed. It is important to note that the fire frequency resulting from the use of unplanned prescribed fire is not necessarily the "natural" frequency or a prescribed frequency.

The re-introduction of fire into wilderness areas through prescribed burning practices has been widely implemented in open, high-canopied forest landscapes which have natural fire regimes characterized by frequent low-intensity (kW/m) surface fires e.g., ponderosa pine (*Pinus ponderosa* Laws.), long-leaf pine (*Pinus palustris* Mill.), slash pine (*Pinus elliottii* Engelm.), loblolly pine (*Pinus taeda* L.) and short-leaf pine (*Pinus echinata* Mill.) forests and sequoia (*Sequoiadendron giganteum* Lindl.) and oak (*Quercus* spp.) savannas (Chapman 1947; Cooper 1960; Habeck and Mutch 1973; Kilgore and Taylor 1979; White 1983). In these systems it appears that fire frequency has been reduced by fire suppression activities because frontal attack of these low-intensity fires is often successful. Consequently, surface and intermediate height (ladder) fuels accumulate and allow for the development of infrequent, high-intensity, stand-replacing crown fires (Van Wagner 1977), a fire regime markedly different from the historic fire regime. In these landscapes, prescribed fire has been used to reduce the accumulated load of surface and intermediate height (ladder) fuels and then to reintroduce, in a controlled manner, a frequent, low-intensity fire regime (Biswell 1989).

In closed-canopied coniferous forests (such as boreal and subalpine forests), the landscape use of prescribed fires to replace the natural fire regime has been proposed based on the following assumptions:

- Past fire suppression has reduced the area burned by wildfire and has therefore decreased the fire frequency from natural levels creating an "older" forested landscape
- "older" forests are often more fire prone than "younger" forests
- Prescribed fires can be used to recreate and maintain younger stands, which will reduce fire hazard (Habeck and Mutch 1973; Heinselman 1973; Loope and Gruell 1973; Romme 1982; Heinselman 1981; McCune 1983; White 1985; Knight 1987).

These assumptions are often accepted without empirical data, since they seem intuitively correct, and methods for testing them have not been widely used. This paper will examine the basis upon which the use of landscape prescribed fire is dependent. To do this, we will address three questions:

- Is there any evidence that fire frequency has been reduced by fire suppression so that fire must be re-introduced into this landscape?
- Why has fire suppression been ineffective in changing the fire frequency in this landscape despite the diligent efforts by fire suppression agencies?
- Can prescribed fires prevent large wildfires?

This paper is concerned with prescribed burning practices within intact wilderness forests, specifically the subalpine forests of the southern Canadian Rockies. It does not address prescribed burning practices specific to harvested forests which are designed to reduce the postharvest fuel hazard, such as slash burning, or to prepare a suitable seedbed for regeneration.

## STUDY AREA

The study area includes Banff, Kootenay and Yoho National Parks and the Bow-Crow Forest Reserve. It is an area of approximately 20,500 $km^2$ and is situated within the southern Canadian Rockies (Figure 1). This region is largely forested with a minimum number of roads, few towns, and essentially no private dwellings. The Dominion Lands Act of 1879 set aside the region for watershed and timber protection, barring homesteading and most permanent settlement. Lumbering, hydroelectric development and some coal mining have been permitted; however, these

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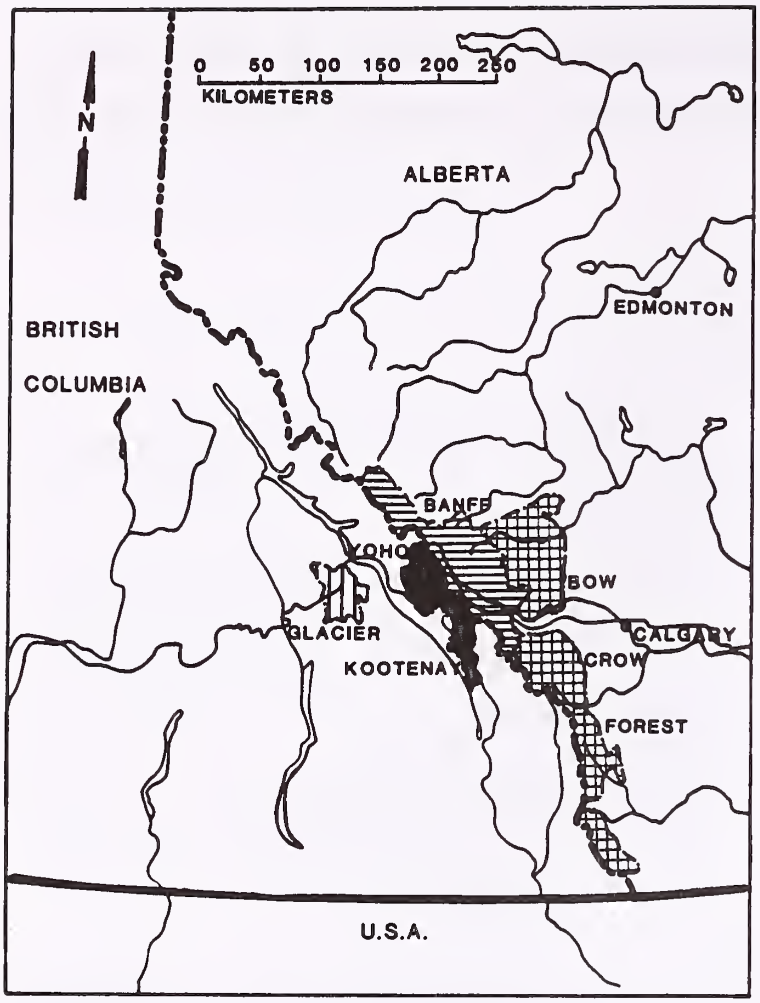


**Figure 1**—The study area, a 20,500-km² area of the southern Canadian Rockies comprised of Banff, Kootenay, and Yoho National Parks and the Bow Crow Forest Reserve.

developments have had only localized effects on the vegetation pattern (Johnson and Fryer 1987). Forest disease or insect outbreaks have also been of very limited importance in the past.

The subalpine forest of the front and main ranges of the southern Canadian Rockies consists of two zones. The lower subalpine zone extends from approximately 1,200 to 1,700 m and is forested by lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), Engelmann spruce (*Picea engelmannii* Parry ex Engel.), white spruce (*Picea glauca* (Moench) Voss), trembling aspen (*Populus tremuloides* Michx.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). The upper subalpine zone, extending from approximately 1,700 to 2,300 m, is dominated by Engelmann spruce and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.). Population dynamics of lodgepole pine and Engelmann spruce in the lower subalpine forest are given in Johnson and Fryer (1989).

The fire season extends from May to early October with most lightning fires occurring during July and August.

# DISCUSSION

## Has Fire Frequency Been Reduced by Fire Suppression, Requiring Fire to be Reintroduced?

This question is central to landscape fire management in natural areas and requires an understanding of fire frequency. Fire frequency is the average proportion of the study area which burns per year. To determine the fire frequency of a study area requires estimating its time-since-fire (survivorship) distribution. It is essential to keep in mind that fire frequency describes a distribution and that comparison of fire frequencies implies a comparison of distributions (see Johnson and Gutsell 1994).

Fire suppression in recent decades is believed to have reduced fire frequency, resulting in older forests and increased fuel accumulation (Habeck and Mutch 1973; Loope and Gruell 1973; Heinselman 1973; Tande 1979; Heinselman 1981; McCune 1983; White 1985). In order to determine the influence of fire suppression programs, time-since-fire distributions prior to and since the programs' implementation must be compared to determine if they are significantly different.

Time-since-fire distributions derived from stand origin maps (Figure 2) have been published for the Kananaskis Valley in the Bow Crow Forest Reserve, Yoho National Park and Kootenay National Park (Masters 1990; Johnson and Larsen 1991; Tymstra 1991). All of these survivorship distributions show a significant break in the fire frequency distribution in the mid-1700's indicating a change from more frequent fires to less frequent fires. The regional consistency in the timing of this change indicates its causal mechanism operates on a large scale. This observed change in fire frequency has been found to correspond closely to the onset in the early 1700's of a cool-moist period known as the Little Ice Age (Luckman 1986; Osborne and Luckman 1988). The occupation of this area by Europeans in the 1880's, the imposition of laws forbidding the landscape use of fire by native North Americans, and the initiation of concerted fire suppression activities within the last 50 years have produced no detectable change in fire frequency in the time-since-fire distributions for the Kananaskis Valley and Yoho National Park (see Figure 2).

The apparent change in fire frequency in the time-since-fire distribution for Kootenay National Park after 1930 is not statistically significant (Masters 1990). However, weather records for this area do indicate an increased average summer precipitation since 1930, which coincides with this apparent decrease in fire frequency.

It has been suggested that fire suppression is particularly effective at preventing "hold over" fires which start under moist fuel conditions and persist until drier fuel conditions allow them to spread. By extinguishing these fires before fuel moisture conditions change and allow larger burns, fire suppression is believed to reduce fire frequency. Such reduction should be apparent in the empirical time-since-fire distributions; however, no significant change has been detected.

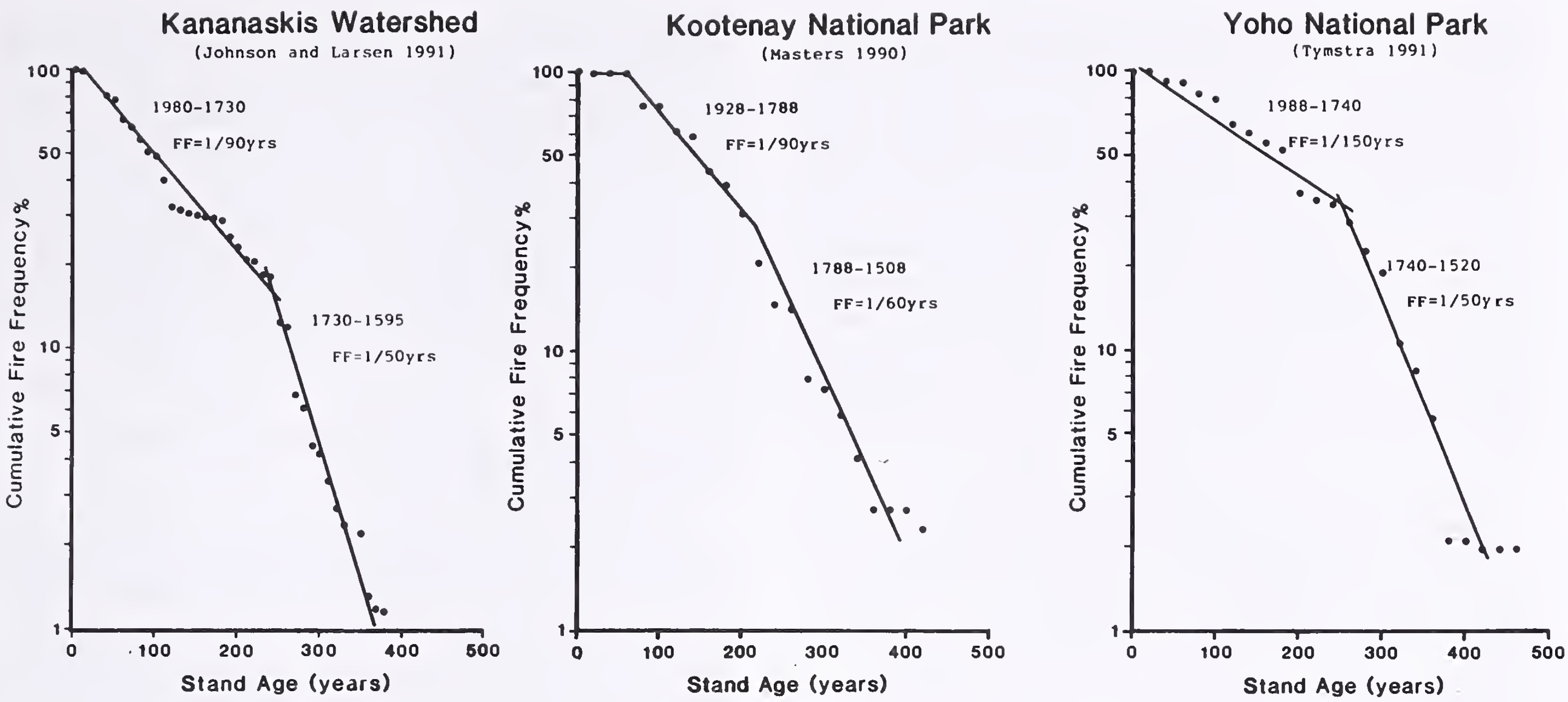


**Figure 2**—The time-since-fire distributions of closed-canopied coniferous forests within wilderness areas of the southern Canadian Rockies. Fire frequency (FF) is the average probability of an element burning per unit time (years) and is the inverse of the fire cycle.

Studies of fire frequency in closed-canopied coniferous forests within wilderness areas of the southern Canadian Rockies show no significant change in the past 100 years that can be explained by the influence of fire suppression. Since there is little evidence to support the belief that fire suppression has reduced fire frequency, wildland prescribed burning is not required to reintroduce fire into this landscape.

## Why has Fire Frequency Been Unchanged by Fire Suppression?

In the closed-canopied coniferous forest of the southern Canadian Rockies, lightning-caused wildfires have accounted for 95% of the area burned in the last three decades (unpublished fire records, Alberta Forest Service and the Canadian Parks Service). Johnson and Wowchuk (1993) found that 3% of these lightning-caused wildfires account for 95% of the area burned. Most fires remain small, but a few occur under conditions which allow them to increase rapidly in size. Only this 3% of fires influence the area burned and fire frequency.

In years with a large area burned, fires in the Rocky Mountains (Anderson 1968; Alexander and others 1983; Fryer and Johnson 1988) characteristically have high intensities (>7,000 kW/m), high rates of spread (≥10 m/min) and high duff consumption (>3 kg/m²). Under these conditions, extreme fire behavior is preceded by a persistent anomalous high pressure system which produces prolonged periods of above normal temperatures and below normal precipitation (Newark 1975; Harrington and Flannigan 1987), and leads to the severe drying of both medium and heavy fuels. This extreme fire behavior exhibits little difference between aspect, elevation and vegetation type (Anderson 1968; Alexander and others 1983; Nimchuk 1983; Janz and Nimchuk 1985; Street 1985; Flannigan and Harrington 1988; Fryer and Johnson 1988). In years with only a small area burned, differences in aspect, slope, elevation and vegetation composition can have a significant effect on the fire behavior (Alexander and McAlpine 1987); however, the area burned in these years is insignificant.

The extreme fire behavior associated with persistent high pressure systems results in large areas burned. During these years, it is unlikely that fire suppression can significantly influence the total area burned.

## Can Prescribed Fires Prevent Large Wildfires?

In closed-canopied coniferous forests within wilderness areas of the southern Canadian Rockies prescribed burning has been proposed as a means of disrupting the continuity of forest fuels by changing the age mosaic of the landscape. This management action is based on the assumption that younger forests act as fire breaks on the landscape and consequently reduce the likelihood of large wildfires (White and Pengelly 1992).

This assumption stems from the belief that the probability of burning increases and fire behavior changes as forests age and fuels accumulate (Habeck and Mutch 1973; Loope and Gruell 1973; Heinselman 1973; Romme 1982; Knight 1987). Consequently, if the proportion or arrangement of younger to older forests in the landscape were managed, then the size and behavior of fires could be controlled.

The detailed argument is as follows: In closed-canopied coniferous forests the forest age-mosaic is managed to create adjacent stands of different age and therefore different flammability. The flammability-aging pattern postulates

that very young stands have a high hazard of wildfire, exhibiting high rates of spread and high intensity. This potential hazard is high because surface fuels, in the form of dead, fire-killed trees, have fallen to the ground, and regenerating trees, shrubs and herbaceous plants accumulate on the forest floor. Young- to middle-aged stands have the lowest potential hazard of high-intensity and high-rate-of-spread fires since crown bases are elevated and understory vegetation has become sparse. In older stands, the forest canopy has become open due to the senescence of canopy trees, the forest floor is again littered with medium and large fuels, and advanced regeneration is increasingly abundant. Consequently, older forests have a higher hazard of crown fires, since they can support higher intensity ground fires and possess vertically continuous (ladder) fuels.

Clearly, this argument suggests that a definite aging pattern should be apparent in the time-since-fire distributions and in the spatial pattern of adjacent ages in the forest age-mosaic. The time-since-fire distributions for the southern Canadian Rockies (Figure 2), however, all exhibit a negative exponential distribution (Van Wagner 1978; Masters 1990; Johnson and Larsen 1991; Tymstra 1991), a model

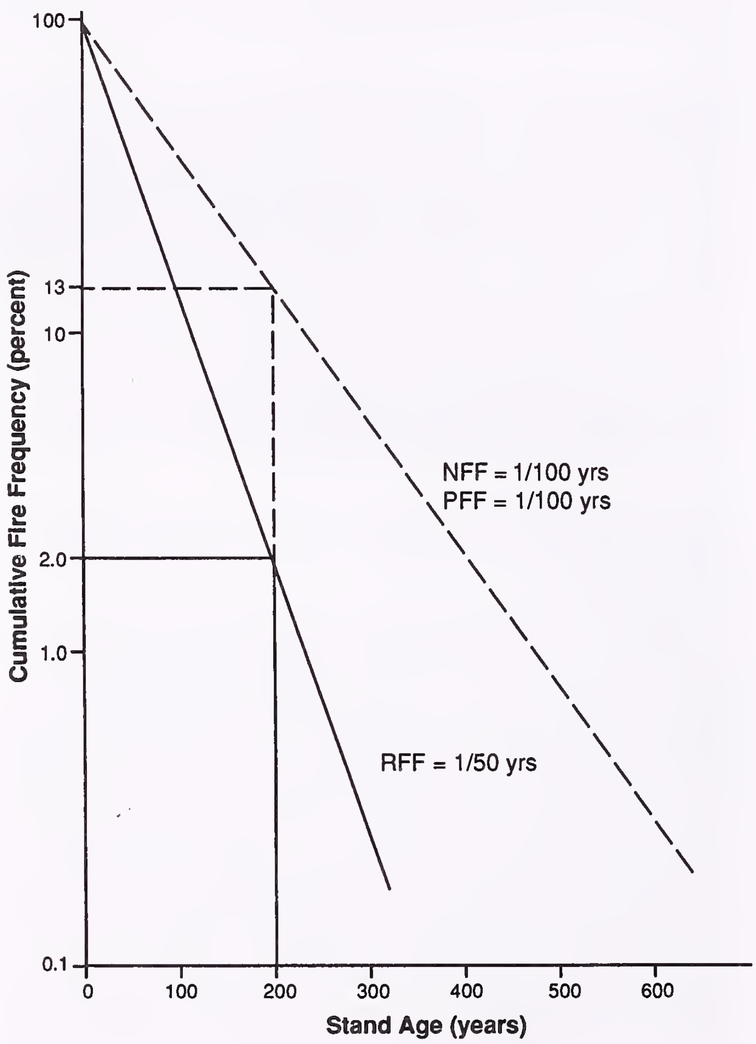


**Figure 3**—Both natural (NFF) and prescribed fire frequencies (PFF) are one for every 100 years. When they are added together, the resultant fire frequency (RFF) is one for every 50 years, assuming natural and prescribed fire frequencies are operating independently of each other.

which indicates no age effect in the probability of burning (Johnson and Van Wagner 1985). Thus, past fires have not stopped when burning into younger or older stands except as would be expected by chance (Johnson and Larsen 1991; Johnson 1992). Clearly, a constant hazard of burning over stand age is consistent with the extremely dry fuel conditions under which large fires have been shown to occur.

Prescribed burning practices designed to prevent the development of large wildfires by creating fire barriers of young forest throughout the landscape are not supported by evidence obtained from fire frequency studies.

## What Could be the Consequence of Reintroducing Fire?

The impact of fire management actions on the landscape can be addressed by examining the time-since-fire distribution that would result. Fire managers would like to implement a prescribed burning program designed to completely replace the natural fire frequency. This management action assumes that wildfire suppression has completely removed natural fire from the landscape. In this case, the prescribed fire frequency, say for example one for every 100 years, would replace the wildfire frequency. However, if fire suppression has not effectively removed wildfire from the landscape, the natural and prescribed fire frequencies are simply additive.

Figure 3 shows that adding a prescribed burning frequency of one for every 100 years to a wildfire frequency of one for every 100 years would increase the fire frequency of the landscape to one for every 50 years. In other words, the increased fire frequency would result in the reduction of the average time-since-fire (fire cycle) of the forested landscape from 100 to 50 years. A consequence of this addition would be to reduce the percentage of the landscape older than 200 years from approximately 13 percent to 2 percent.

If fire was reintroduced on a landscape scale in order to replace the natural fire regime that was falsely thought to be nonexistent, due to fire suppression, the resultant disturbance frequency would increase, causing a reduction in the average age of the forested landscape.

## CONCLUSIONS

What fire management strategy would be most appropriate in natural or wilderness areas of closed-canopied coniferous forests? Any fire management program must recognize that suppression of fires during the infrequent years of extremely dry fuel moisture may never be possible, but that suppression during low and moderately dry fuel years will be possible. Consequently, at least two strategies present themselves. The first strategy is to continue to attempt suppression of all fires but recognize that suppressible fires would probably have remained small even if they were not suppressed. The second strategy is to allow most wildfires to burn except where public safety, administrative boundaries, and facilities are threatened. Both strategies recognize that large fires will occur in extremely dry years and may be unsuppressible. Consequently, facilities and visitor use should be planned and managed with these large fires in mind. In preparation for these large fires, frequent, localized fuel management (fire breaks) around facilities,

roads, trails and other priority areas should be performed to facilitate protection from fire. A prescribed fire plan like this has been suggested for Yellowstone National Park (Brown 1989). The result of this policy will allow the lightning fire regime to determine the vegetation age structure and pattern of the landscape; however, public safety, facilities, roads, and other priority areas will be protected. This is a policy based on the realities of the suppression capacities as they exist today and our current understanding of lightning fire frequency and behavior.

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# Evaluation of the Banff National Park Planned Ignition Prescribed Fire Program

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Fires in Banff National Park burned on average about 32,000 ha per decade prior to 1880 (White and Pengelly 1992). Increasingly effective fire control since that time (White 1985, Day and others 1990) has continually reduced the burned area (Table 1). Banff National Park is attempting to duplicate natural processes as closely as possible by igniting prescribed fires (Lopoukhine and White 1985). The frequency and pattern of fire use in the Park's ecosystem should maintain habitat conditions for native wildlife and vegetation species while protecting park facilities and neighboring lands.

Since 1983, the Park's fire program has burned about 5,200 ha of subalpine and montane forest (Table 1). Most units were lit with aerial ignition. Fire intensities ranged from large areas of crown fire to numerous stands that were surface burned or not burned at all. Because the Park is not burning in peak mid-summer conditions, it is possible that current prescribed fires are systematically missing cooler and moister aspects that were burned by historic fires. Further, aerial ignition creates fire behavior—such as high-energy convection columns from mass ignition patterns—that is possibly different from wind-driven fires.

The ongoing evaluation of the program is statistically testing similarities and differences (in terms of forest mortality) between prescribed fires and historic natural fires on the same points. Another component of the study deals with the applicability of Landsat Thematic Mapper data for monitoring fire effects. The main objective here is to determine the usefulness of satellite data in delineating fire perimeter and stratification of burned areas into crown, surface, and unburned zones.

## METHODOLOGY

We selected five representative burn units, totaling over 2,000 ha, that reflect the ecological and landscape diversity of locations subjected to planned ignition. The size of the units varies from 86 ha (Two Jack I and II) to 1,200 ha (Minnewanka I). All sites occupy montane and subalpine ecoregions of Banff National Park (Holland and Coen 1982).

### Field Sampling Design

To avoid duplication of expensive and time-consuming field work, the ground sampling procedure meets the requirements of both the "burn pattern evaluation" and "Landsat testing" study components. In each study we lay out a dense network of transects, based on a regularly spaced grid of 100 m by 100 m sampling plots. To fully account for each unit's biophysical diversity, additional plots are identified on aerial photographs. A hand-held Global Positioning System (GPS) unit increases speed and precision in locating designated transects and sample plots (necessary for conducting supervised classification of Landsat data). The battery-operated, Sony IPS 360 Pyxis GPS receiver gives positions with an accuracy of 30 to 100 m. Tests completed before the commencement of field work showed that the unit was consistently accurate within a range of 50 m.

Data collected on the plots and along the transects includes information on the intensity of the prescribed burn (crown, surface, unburned) and past fire history (evidence of past fire and its intensity). This requires extensive collections of tree cores and cross-sections. Aspect, elevation, slope percentage, and ocular estimation of exposed bedrock are also recorded. Vegetation is keyed to the types used in

**Table 1**—Banff National Park area burned and number of fires (>40 ha) for natural and historic periods (from White 1985 and White and Pengelly 1992)

| Period | Area burned (ha) Wildfires | Prescribed fires | Number of fires (>40 ha) |
|---|---|---|---|
| Natural Decade | 32,000 | — | — |
| 1880-1889 | 37,050 | — | >6 |
| 1890-1899 | 18,600 | — | 9 |
| 1900-1909 | 16,050 | — | 12 |
| 1910-1919 | 3,300 | — | 6 |
| 1920-1929 | 10,950 | — | 9 |
| 1930-1939 | 8,050 | — | 6 |
| 1940-1949 | 4,200 | — | 2 |
| 1950-1959 | 0 | — | 0 |
| 1960-1969 | 500 | — | 1 |
| 1970-1979 | 45 | — | 1 |
| 1980-1989 | 0 | 2,517 | 5 |
| 1990-1992 | 0 | 2,710 | 6 |

In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

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the ecological land classification of Banff National Park (Holland and Coen 1982). A series of oblique color photographs obtained from a helicopter helps determine the precise spatial distribution of planned ignition burning patterns. The helicopter platform is too unstable to acquire a consistent stereoscopic coverage of the area. Nevertheless, the large scale of the photographs (approximately 1:2,000) allows for easy identification of tree species and burn patterns. Crown closure is estimated from panchromatic aerial photographs and verified on the ground.

Upon completion of the field work these data will be subject to regression and discriminant analyses to determine whether there is a statistically significant relationship between the planned ignition pattern and biophysical descriptors of prescribed burning sites, and the sites' fire history. Additionally, paired sample tests will determine whether relationships exist between planned ignition patterns and natural fire patterns. Cases where field data are inconclusive will be exempt from the statistical analysis.

## Application of Landsat Thematic Mapper Data

The cost of monitoring the effects of prescribed burning is high. The amount of time required for such a program is estimated to be several weeks a year, provided that the area burned annually does not exceed 1,000 ha. The only viable alternative to conventional field work seems to be the employment of remote sensing technology. Repetitive acquisition of aerial photographs is impractical due to their high cost and to logistical constraints. For these reasons Banff National Park decided to test the applicability of Landsat Thematic Mapper data as a relatively inexpensive and readily available source of information.

We evaluated several approaches to map forest fire effects with Landsat data. The majority of studies in this area involve digital processing of multispectral data. Supervised classifications are used to delineate burn classes. These give results comparable to those obtained through the analysis of the post-burn color infrared photographs. A study on wildfire effects in Seney Wildlife Refuge (Michigan) revealed that only light surface burn areas could not be discriminated from unburned forest on Landsat images. Additionally, the two organic burn categories identified on infrared photographs had to be combined on Landsat images into one burn class (Lachowski 1979).

Other digital transformations (mainly image enhancements) of Landsat data emphasize the specific response of burned vegetation to electromagnetic radiation. For example, in burned areas Landsat Thematic Mapper band 4 registers less reflectance due to the lack of green foliage, which normally reflects the bulk of near infrared radiation. On the other hand, band 3 registers stronger reflectance. A lack of green foliage results in red light being reflected, instead of being absorbed by chlorophyll in the process of photosynthesis. Thematic Mapper band 6 registers stronger emission from burned areas; the reduction of vegetation cover results in less surface cooling associated with the evapotranspiration process. The values of band 7 are inversely correlated to the moisture content. Burned areas have diminished soil moisture (from increased exposure to solar radiation) and drier foliage, resulting in high values on band 7. On the basis of these theoretical considerations, Reinhardt and Ringleb (1991) generated a fire effects map by dividing the values for band 4 (Landsat Thematic Mapper) by the average of bands 3, 6 and 7 and multiplying the resulting ratio by 64. This conversion was designed to maximally enhance the difference between unburned and burned vegetation, and to allow the stratification of the severity of burns.

In the Banff National Park study we are conducting both image enhancement techniques and spectral classification. Employment of Global Positioning System Technology to locate training sites should improve the quality and accuracy of supervised classification. Given elevation influences on spectral reflectance of vegetation, we will use digitized elevation data as one of the classification factors. A comparison of pre- and post-fire "vegetation indexes" (Lo 1987) from Landsat data will be used to evaluate the post-fire reduction of the green mass of forest stands. Initially, digital processing of Landsat data will be conducted on a Bull RS/6000 Model 220 workstation (IBM) using the PCI system of programs for image analysis. In our quest for the most cost-effective method, a significantly cheaper IBM PC-based software (EIDETIC image analysis system) will also be tested. Ground verification and cost-versus-accuracy analysis will determine the applicability of both systems.

## STUDY SCHEDULE

In the 1992 field season over 100 plots were completed. About 10% of the plots were not visited due to inaccessibility of the terrain. During the 1993 season we will complete the remaining 150 plots and conduct a detailed ground verification of the satellite data. Study results should be available in the spring of 1994.

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Includes 75 papers dealing with fire in wilderness and park management. The general themes are attaining wilderness management goals, addressing management constraints, and implementing programs. Papers address topics such as air quality, community and political concerns, prescribed fire, fire effects, fire ecology, fire danger, fire suppression, the media, and public opinion.

Keywords: fire effects, fire ecology, prescribed fire, fire danger, fire suppression, public opinion, air quality



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